DOCUMENT RESUME

ED 195 390 SE 033 067

TITLE	A Course on Troubleshooting O & M Problems in Wastewater Treatment Facilities. Course Number 179.2. Instructor Notebook.
INSTITUTION	Southern Illinois Univ., Carbondale.
SPONS AGENCY	Office of Water Program Operations (EPA), Cincinnati, Ohio. National Training and Operational Technology Center.
PUB DATE	Dec 79
GRANT	EPA-T-900783-01-1
NOTE	1,756p.: Pages T3.2.5-T3.2.18 removed due to copyright restrictions. Some tables may be marginally legible.
EDRS PRICE	MF15/PC71 Plus Postage.
DESCRIPTORS	Environmental Standards: Instructional Materials: Postsecondary Education: *Sanitation: *Technical Education: Technology: *Utilities: *Waste Disposal: *Water Pollution: Water Resources
IDENTIFIERS	*Waste Water Treatment

ABSTRACT

Intended for persons associated with wastewater treatment plant operations and management (O&M), the course described is designed to address significant factors contributing to poor plant performance. The training materials discuss the interaction between several potential causes of problems and stress the need for comprehensive corrective action programs. Following a set of guidelines for the course director, 15 units of instruction are presented. These contain a total of 49 lessons and are generally offered as a 30-35 hour short course. In addition to the 12 units which deal directly with O&M problems are introductory and closing units and a unit which examines elements of the troubleshooting process. Each lesson plan includes the purpose, trainee entry-level behaviors, objectives, schedule, materials, classroom setup, lesson outline, and references. All materials that appear in a trainee's notebook or which should be reproduced as handouts are located after corresponding lessons. Instructional approaches range from lectures to simulations, analyses of records, and small group problem-solving sessions. The course is designed to help trainees develop a set of basic tools to apply in a variety of O&M situations. (WB)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED195390

U S DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

A COURSE ON

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

COURSE NUMBER 179.2
ENVIRONMENTAL PROTECTION AGENCY
NATIONAL TRAINING AND OPERATIONAL TECHNOLOGY CENTER
CINCINNATI, OHIO 45268

INSTRUCTOR NOTEBOOK

DECEMBER, 1979

This course was developed by the
Environmental Resources Training Center
of Southern Illinois University
in cooperation with the
National Training and Operational Technology Center
of the
Environmental Protection Agency
under Grant No. T-900783-01-1.

SE 033 067

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

INSTRUCTOR NOTEBOOK

Table of Contents

Page No.

Foreword i

Acknowledgements iv

Guidelines for the Course Director

- Origin, Philosophy and Background of the Course v
- Course Objectives vi
- Trainee Selection viii
- Educational Approach ix
- Responsibilities of the Course Director x
- Options for Scheduling
  - Training Materials x
  - Adjusting the Course Length xii
  - The Minimum Course xii
  - Alternate Presentation Formats xiii
  - Designing Your Course xiii
- Instructors xiv
- Physical Setting and Group Activities xv
- Use and Preparation of Materials xvi
- Unit Plan Use and Mechanics xvii
- Format of the Instructor Notebook and Trainee Notebook Materials xviii
- Availability of Training Materials xxii
- Other Logistics xxii

Page No.

Appendices

Appendix A: Inventory of Training Materials A-1

Appendix B: Training Materials to be Ordered B-1

Appendix C: Summary of Course C-1

Appendix D: Checklist of Activities for Presenting the Course D-1

Unit of Instruction 1. Overview

Instructor Overview of Unit 1.1

Lesson 1. Welcome, Introduction and Orientation 1.1.1

Trainee Notebook Materials T1.1.1

Lesson 2. Trainee Assessment 1.2.1

Trainee Assessment - Answer Sheet Key 1.2.7

Trainee Handout Materials

Trainee Assessment - Answer Sheet H1.2.1

Trainee Assessment H1.2.3

Lesson 3. Significance of Plant O & M 1.3.1

Trainee Notebook Materials T1.3.1

Lesson 4. Evaluating Treatment Plant Operations - A Board Game 1.4.1

Unit of Instruction 2. Elements of Troubleshooting

Instructor Overview of Unit 2.1

Lesson 1. Attitudes and Human Behavior in Troubleshooting 2.1.1

Trainee Notebook Materials T2.1.1

Lesson 2. The Process of Troubleshooting 2.2.1

Trainee Notebook Materials T2.2.1

Page No.

Unit of Instruction 3. Sewer Use Control

Instructor Overview of Unit 3.1

Lesson 1. Applying the Process of Troubleshooting to Collection System Problems 3.1.1

Trainee Handout Materials

Problem No. 1. Fact/Answer Sheets H3.1.1

Problem No. 2. Fact/Answer Sheets H3.1.4

Solutions to Problems H3.1.7

Lesson 2. Sewer Use Control and Industrial Waste Monitoring 3.2.1

Trainee Notebook Materials T3.2.1

Unit of Instruction 4. Pre/Primary Treatment

Instructor Overview of Unit 4.1

Lesson 1. Preliminary Treatment 4.1.1

Trainee Notebook Materials T4.1.1

Lesson 2. Primary Treatment 4.2.1

Trainee Notebook Materials T4.2.1

Unit of Instruction 5. Fixed Media Biological Systems

Instructor Overview of Unit 5.1

Lesson 1. Troubleshooting Fixed Media Biological Systems . 5.1.1

Trainee Notebook Materials T5.1.1

Lesson 2. Applying the Process of Troubleshooting 5.2.1

Trainee Notebook Materials T5.2.1

Unit of Instruction 6. Oxidation Lagoons

Instructor Overview of Unit 6.1

Page No.

Lesson 1. Troubleshooting Oxidation Lagoons 6.1.1

Trainee Notebook Materials T6.1.1

Lesson 2. Applying the Process of Troubleshooting 6.2.1

Trainee Notebook Materials T6.2.1

Unit of Instruction 7. Laboratory Practices

Instructor Overview of Unit 7.1

Lesson 1. The Laboratory as a Tool for Process Control and Troubleshooting 7.1.1

Lesson 2. Troubleshooting Laboratory Practices 7.2.1

Trainee Notebook Materials T7.2.1

Lesson 3. Laboratory Equipment 7.3.1

Trainee Notebook Materials T7.3.1

Unit of Instruction 8. Flow Measurement

Instructor Overview of Unit 8.1

Lesson 1. Flow Measurement and Treatment Plant Operations 8.1.1

Trainee Notebook Materials T8.1.1

Lesson 2. Troubleshooting Treatment Plant Flow Problems 8.2.1

Trainee Notebook Materials T8.2.1

Unit of Instruction 9. Chemical Additions

Instructor Overview of Unit 9.1

Lesson 1. Using Chemicals to Upgrade Treatment Plants . . 9.1.1

Trainee Notebook Materials T9.1.1

Lesson 2. Troubleshooting Plants with Chemical Additions . 9.2.1

Trainee Notebook Materials T9.2.1

Page No.

Unit of Instruction 10. Management Behavior

Instructor Overview of Unit 10.1

Lesson 1. Management/Administration and Treatment Plant Operations 10.1.1

Trainee Notebook Materials T10.1.1

Lesson 2. Troubleshooting Management Systems 10.2.1

Trainee Notebook Materials T10.2.1

Lesson 3. Managerial Functions 10.3.1

Trainee Notebook Materials T10.3.1

Unit of Instruction 11. Activated Sludge

Instructor Overview of Unit 11.1

Lesson 1. Introduction to Activated Sludge Process Troubleshooting 11.1.1

Trainee Notebook Materials T11.1.1

Lesson 2. Process Control Concepts for Activated Sludge . 11.2.1

Trainee Notebook Materials T11.2.1

Lesson 3. Activated Sludge Process Variations 11.3.1

Trainee Notebook Materials T11.3.1

Lesson 4. Microscopic Evaluation of Sludge 11.4.1

Trainee Notebook Materials T11.4.1

Lesson 5. Process Control Based on Sludge Settleability. . 11.5.1

Trainee Notebook Materials T11.5.1

Lesson 6. Respiration Rate Control Procedures 11.6.1

Trainee Notebook Materials T11.6.1

Page No.

Lesson 7. Identifying Problem Causes in Activated Sludge 11.7.1

Trainee Notebook Materials T11.7.1

Trainee Handout Materials

Problem Identification and Process Control Response-Answer Sheets H11.7.1

Lesson 8. Visual Observations in Troubleshooting 11.8.1

Lesson 9. Case History: Pullman Treatment Plant 11.9.1

Trainee Notebook Materials T11.9.1

Lesson 10. Case History: Pullman Treatment Plant - Solution 11.10.1

Trainee Handout Materials

Pullman Wastewater Treatment Facility - Solution Implemented H11.10.1

Lesson 11. Hamsborough Case History 11.11.1

Trainee Notebook Materials T11.11.1

Lesson 12. Sludge Settling Problems 11.12.1

Trainee Notebook Materials T11.12.1

Lesson 13. Mini-Case Histories 11.13.1

Lesson 14. Unit Summary 11.14.1

Trainee Notebook Materials T11.14.1

Unit of Instruction 12. Solids Handling

Instructor Overview of Unit 12.1

Lesson 1. Anaerobic Digestion 12.1.1

Trainee Notebook Materials T12.1.1

Lesson 2. Problem Solving in Anaerobic Dgiestion 12.2.1

Trainee Notebook Materials T12.2.1

Trainee Handout Materials

Page No.

Instructions to Operating Personnel - Problem Number 1 . . . . H12.2.1

Instructions to Operating Personnel - Problem Number 2 . . . . H12.2.3

Lesson 3. Other Methods of Solids Handling 12.3.1

Trainee Notebook Materials T12.3.1

Lesson 4. Tall Tales or "Where Did All That Sludge Come From?". 12.4.1

Lesson 5. Applying the Process of Troubleshooting 12.5.1

Unit of Instruction 13. Land Treatment

Instructor Overview of Unit 13.1

Lesson 1. Land Treatment Systems 13.1.1

Trainee Notebook Materials T13.1.1

Lesson 2. Troubleshooting Operational Problems 13.2.1

Trainee Notebook Materials T13.2.1

Unit of Instruction 14. Disinfection

Instructor Overview of Unit 14.1

Lesson 1. Chlorination 14.1.1

Lesson 2. Ozonation 14.2.1

Trainee Notebook Materials T14.2.1

Unit of Instruction 15. Closing

Instructor Overview of Unit 15.1

Lesson 1. Course Summary 15.1.1

Lesson 2. Post-Test 15.2.1

A COURSE ON TROUBLESHOOTING
O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Foreward

PL 92-500, the 1972 Amendment of the Federal Water Pollution Control Act, established a goal to clean up the nation's waterways to achieve "fishable and swimable" water quality by the 1980's. The law provided a Federal Construction Grants program to assist municipalities in the design and construction of publicly owned treatment works to provide treatment facilities needed to meet this goal. The law further provided that the Environmental Protection Agency in cooperation with the states would establish water quality criteria consistent with this goal and would implement and enforce a National Pollutant Discharge Elimination System (NPDES) permit program which would define upper limits for point source discharges from publicly and privately owned treatment works.

Annual surveys of the performance of treatment works constructed under the Federal grants program disclose that less than half of all publicly owned secondary treatment facilities are performing at or better than design efficiency. Subsequent research funded by the EPA shows that many factors adversely affect treatment works and contribute to poor performance. Most significant among these are (1) the failure of operations personnel to understand and apply wastewater treatment principles in process control of the facilities, (2) the failure of operations personnel to perform laboratory tests and to interpret and apply test results to process control, (3) the failure of technical assistance personnel, such as design consultants, state and federal agency personnel and instructors of wastewater treatment technology courses, to give proper technical guidance to operations personnel, (4) the failure of design consultants, equipment manufacturers and contractors to provide controllable and operable treatment facilities, and (5) the failure of facility owners to provide effective and workable management, administration and fiscal support to the wastewater treatment facility.

Seldom will one find that poor performance at a wastewater treatment facility can be attributed to a single causative factor. Typically, all factors will be encountered. When problems attributed to one cause are solved, other problems which derive from completely different causes will frequently surface. Thus problem solving at wastewater treatment facilities must be multidisciplinary and involves many participants: the plant operator, the plant design consultant, the operations consultant, the plant management, and the facility owner, among others. A corrective action program which is addressed to only one factor is doomed to failure.

The course *Troubleshooting O & M Problems at Wastewater Treatment Facilities* is one effort by the EPA to provide a capability to evaluate wastewater treatment facilities and to improve their performance. The course materials contained herein address directly four of the five most significant factors contributing to poor plant performance. Although design for O & M is not addressed directly, the course also provides information which could be incorporated by the design profession to improve the operability and controllability of wastewater treatment facilities. The course addresses the interaction between the several potential causes of problems, stresses the need for comprehensive corrective action programs and guides the trainee toward broader based corrective programs.

Troubleshooting O & M Problems at Wastewater Treatment Facilities offers significant benefits through training directed to at least six target populations. These target populations are:

1. Plant operations and management personnel who are responsible for implementing and monitoring process control programs at the facility;

2. Federal, state and local regulatory agency personnel who are responsible for O & M evaluations at wastewater treatment facilities and who recommend improved or alternate operational procedures to plant personnel;

3. Private sector operations consultants who provide technical assistance services to wastewater treatment facility owners and their operations personnel;

4. Design consultants who provide design, start-up and technical assistance services to clients;

5. Equipment manufacturers and their representatives who supply and service the equipment found in the facility and interface the operation of their equipment with the total system operation; and

6. Instructors of wastewater technology courses who train plant operations personnel, design professionals and others.

The training materials presented herein are readily adaptable for presentation to each of the target populations identified. Only minor changes in emphasis or tone are required to tailor the materials to the several potential audiences.

Because wastewater treatment plant O & M problems may be very complex and caused by a variety of interactive forces, the course should not be viewed as a cure-all which will provide a solution to any problem. Rather, the course should be viewed as providing a set of basic tools which the trainee can apply in a variety of situations. If properly applied, these basic tools will lead the trainee through a sequence of logical steps which terminate in identification of the problem, isolation of the potential causes, definition of all the solutions applicable to the problem and selection of the preferred solutions.

The success of the course depends on you, the instructor. Review carefully the *Guidelines for the Course Director*. Make sure the course is well organized and that the trainee and instructor materials are available when needed. Most importantly, make sure you're comfortable with the content material. Where necessary, personalize the lesson materials by substituting examples from your own experience which support the course and lesson objectives and which permit you to be a more effective teacher.

Acknowledgements

The materials for *A Course on Troubleshooting O & M Problems in Wastewater Treatment Facilities* were prepared by the Environmental Resources Training Center of Southern Illinois University at Edwardsville in cooperation with the National Training and Operational Technology Center, U.S. Environmental Protection Agency, Cincinnati, Ohio, under Training Grant Number T-900783-01-1.

The training materials contained herein are based in large part on the original materials developed by the American Public Works Association for the Municipal Operations Branch of the U.S. Environmental Protection Agency under Training Grant Number T-900535-01-1 and published in August, 1976.

The Environmental Resources Training Center acknowledges the following individuals who contributed directly and significantly to the development of the revised training materials: Dr. James O. Bryant, Jr., Director, Ms. Susan A. Castle, Program Director, Mr. John L. Krantz, Coordinator and Ms. Nancy A. Harris, Secretary, of the Environmental Resources Training Center, Southern Illinois University, Edwardsville, Illinois; Mr. Charles S. Zickefoose, STRAAM Engineers, Inc., Portland, Oregon; Mr. William R. Hill, Floyd G. Browne and Associates, Ltd., Marion, Ohio; Mr. T. M. Regan, T. M. Regan, Inc., Lexington, Kentucky; Mr. Paul G. Klopping, Linn-Benton Community College, Albany, Oregon; Mr. Lynn Marshall and Mr. Thomas Schwing, National Training and Operational Technology Center, Environmental Protection Agency, Cincinnati, Ohio.

A special note of thanks goes to Mr. James B. Walasek, Project Officer, National Training and Operational Technology Center, Environmental Protection Agency, Cincinnati, Ohio, who persevered through endless problems and delays to see the project through to completion.

James O. Bryant, Jr., Ph.D., P.E.
Director
Environmental Resources Training Center
May 30, 1980

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

GUIDELINES FOR THE COURSE DIRECTOR

The purpose of this section is to provide you, the Course Director, with instructions, guidelines and general information on the staging of the course *Troubleshooting O & M Problems in Wastewater Treatment Facilities*. The course developers hope that the following information will be helpful.

I. *Origin, Philosophy and Background of the Course*

This course grew out of the concerns of the Municipal Operations Branch and the National Training and Operational Technology Center of the U.S. Environmental Protection Agency for the performance of the thousands of wastewater treatment facilities in which this nation has invested billions of dollars.

Early in 1975, EPA asked the American Public Works Association to develop and test an education/training program which would assist employees of state or federal water pollution control agencies with their responsibilities for wastewater treatment plant inspections. Since many of the inspectors were familiar with conducting performance evaluations and in some instances providing technical assistance, it was mutually agreed that the *Process of Troubleshooting* would be the basis for and overriding philosophy of a short-term intensive education/training course. (The *Process of Troubleshooting* is the procedure for identifying and isolating a problem, formulating alternative actions and solutions and combining corrective action with short- and long-range follow-up.) The development of the course was overseen by a Technical Review Committee established by EPA for that purpose.

The American Public Works Association with U.S. Environmental Protection Agency sponsorship presented the course seven times for state and Federal regulatory agency personnel. In early 1977 the Environmental Resources Training Center of Southern Illinois University at Edwardsville under a grant with the National Training and Operational Technology Center made four additional presentations of the course to regulatory agency personnel using the training materials developed and published in August, 1976, by the American Public Works Association. In 1978, the National Training and Operational Technology Center awarded a training grant to the Environmental Resources Training Center of Southern Illinois University at Edwardsville to modify the course materials for use in training private sector consulting engineers in wastewater treatment system evaluation and troubleshooting procedures. Under the latter grant the Environmental Resources Training Center made two presentations of the course to private sector consultants. A final field test of the training materials was conducted by staff personnel of the National Training and Operational Technology Center in the summer of 1979.

The training materials for the course, *Troubleshooting O & M Problems in Wastewater Treatment Facilities*, evolved from the combined experiences of the Environmental Resources Training Center, the American Public Works Association and the National Training and Operational Technology Center in teaching the course. The basic framework, much of the content material and the educational techniques used for the course, were developed by the American Public Works Association. The Environmental Resources Training Center has modified, revised, updated and expanded the training materials but has retained the basic structure and approach developed by the American Public Works Association. In many cases the Environmental Resources Training Center has left the original training material intact with little or no change.

II. *Course Objectives*

Trainees entering the course should be intimately familiar with normal or routine operation and maintenance procedures for wastewater treatment processes and equipment. Before beginning the course, the trainee should be able to do the following:

1. Given a photograph, drawing, schematic or verbal description of wastewater treatment equipment or processes, the trainee will be able to

    a. Identify and name the treatment equipment or process unit;

    b. State the purpose and function of each piece of equipment and each unit in the process;

    c. Identify, point out and name the component parts of the equipment or process;

    d. Describe how each component works and why it is important to the performance of the overall treatment system;

    e. List the typical operating ranges of control parameters for equipment, unit processes and their component parts;

    f. Describe the normal or routine operation and maintenance procedures for equipment, unit processes and their component parts.

2. Given essential design and operating data for equipment, unit processes or treatment systems,
    a. State whether or not the equipment is performing normally;
    b. State whether or not the equipment, unit process or treatrent system in performing satisfactorily.
3. Given access to wastewater treatment equipment, unit processes and systems which are operating well, perform normal or routine process control, operations and maintenance tasks correctly.

At the conclusion of the course the trainee should be able to do the following:

1. From memory, list in chronological sequence the steps in the *Process of Troubleshooting* and describe how the *Process of Troubleshooting* is applied when providing performance evaluation and technical assistance services to a wastewater treatment facility.
2. Given access to a wastewater treatment facility, apply the *Process of Troubleshooting* to evaluate the performance of the treatment facility. Specifically, the trainee should be able to:
    a. Establish effective communication with plant management, plant operating personnel and local, state, Federal and regulatory agency personnel.
    b. Determine information and data needed to evaluate the system's performance, to identify problems and their causes, to list alternative solutions, to select and implement a preferred solution and to evaluate the effectiveness of the solution in improving plant performance.
    c. Gather and analyze available data to identify the problems which are contributing to inadequate performance and to assign the causes among such factors as operation, maintenance, loading, process control procedures and strategy, design, management/administration and other functions.
    d. Analyze data to determine the corrective programs or

procedures most likely to be effective in particular situations and implement corrective actions to improve treatment plant operations and performance.

e. Monitor the short and long term effectiveness of the corrective actions implemented.

3. Given the instructor and student training materials for the course *Troubleshooting O & M Problems in Wastewater Treatment Facilities*, organize and present the training course.

The major thrusts of the course are to develop the trainee's ability to apply a logical sequence of steps in problem solving (the *Process of Troubleshooting*) and to expand the trainees awareness that provision of technical assistance requires both technical expertise and skills in interpersonal relationships and communication. The training techniques used in the course force the trainees to participate in activities which require interpersonal communication skills.

III. *Trainee Selection*

The preferred trainee entry level behavior specifies that trainees be knowledgeable about wastewater treatment operations. The course is designed to build on the trainees knowledge and develop both technical and non-technical problem solving skills. Experience in presenting the course has shown that many trainees do not have the comprehensive skills specified for entry personnel. Therefore, the units of instruction are organized to provide a review of basic operational technology to refresh skills. The "review" lessons could be expanded to tailor the course to a less ambitious entry level behavior.

A related problem surfaces when trainees employed in regulatory or design functions enter the course because their knowledge of plant operations tends to be theoretical and somewhat abstract (book learning) rather than applied. Such trainees frequently perform well on the written pre-test but have difficulty identifying with the operational problems and solutions presented in the course. The course developers have found that including experienced plant operators as trainees in the course with regulatory and design personnel helps overcome this problem. Approximately one-third of class participants should be plant operators or former operators. Care must be taken to assure that plant operators are "paired" with non-operators in assigning the four-person work teams for the course. This causes a synergistic learning as trainees exchange ideas which derive from theoretical and applied perspectives.

Trainees must be carefully screened and selected if they are to derive maximum benefit from the course. Persons having knowledge or experience less extensive than that specified in the entry level have performed well in the course and have derived significant benefit from it when they are teamed with trainees meeting the entry level criteria.

The course relies heavily on trainee interaction in work groups and class discussion sessions. Courses with a predominance of younger trainees lacking in plant operations experience have been less successful than courses with large numbers of experienced trainees. Trainees lacking in operations experience sometimes make only a limited contribution to discussions but learn a great deal from such discussions. However, care must be taken so that the experienced trainees don't dominate the discussion to the point that the lesser experienced trainees are totally excluded.

Classes with more than thirty-two (32) trainees have proven difficult to manage. The course developers recommend that the course enrollment be limited to thirty-two. A class size of twenty-four or twenty-eight trainees is preferred. (Note: The training materials are written for four person trainee work groups. It is a convenience to the Course Director if the number of trainees is a multiple of four.)

IV. *Educational Approach*

Because the key to successful troubleshooting and technical assistance is the working relationship between the troubleshooter and the plant operator, this course stresses human (interpersonal) skills as well as technical skills.

The Course Director should note that the teaching-learning rational of *adult education* is reflected throughout this course. In the trial presentations of this course it was demonstrated that students with the prescribed entry background have much to contribute to each other, by virtue of their experience working at or inspecting wastewater treatment plants. Therefore, the course employs various adult education techniques because adults bring a great deal of insight and information to any given learning situation, and it is important to provide opportunities for the students to learn from each other as well as from the instructor "expert."

This course is built upon a variety of educational techniques to assist in the development of both behavioral and technical skills. As Course Director you will find that case study problem situations are explored by means of lectures, discussions, visuals, record analysis, role playing, simulation games, quizzes and small group interaction techniques. Problem solving is at the heart of most of the lesson approaches. It should be recognized also that potential students for this course are accustomed to a rather highly charged working environment in the field versus a staid classroom setting; and therefore, simulation and participatory activities along with project and case studies help to keep the learning situations from "bogging down" and prevent the students from losing interest.

V. *Responsibilities of the Course Director*

This course generally has been presented as a 30 to 40 hour short course. The principal responsibilities of the Course Director are *preparation and continuity*. It is important that one individual - designated as Course Director - be given the responsibility to coordinate the considerable amount of preparation required as well as serve as on-site director during the presentation of the course. The principal responsibilities of the Course Director include:

A. Scheduling the course
B. Screening and selecting trainees and making necessary arrangements for trainees to attend the course
C. Recruiting (hiring) and briefing instructors
D. Preparation of classroom and teaching facilities
E. Preparation and distribution of course materials
F. Teaching of Unit 1 - *Overview*, and Unit 2 - *Elements of Troubleshooting*. (In many instances, the Course Director would be the preferable instructor for these lessons. The Course Director may teach other units or lessons depending on his/her background and experience.)
G. Maintain continuity throughout the course, from start to finish.

VI. *Options for Scheduling*

A. *Training Materials*

The Instructor and trainee materials for *Troubleshooting O & M Problems in Wastewater Treatment Facilities* are presented as fifteen training modules called Units of Instruction. The fifteen Units of Instruction with titles, unit number, number of lessons in the Unit of Instruction and recommended time for presentation are listed in Table I. The fifteen Units of Instruction cover the majority of liquid and solid waste treatment processes and operations commonly encountered in municipal wastewater treatment facilities. Heat treatment and incineration of waste sludges are not covered in the course materials.

TABLE I. UNITS OF INSTRUCTION

UNIT OF INSTRUCTION	UNIT NUMBER	LESSONS IN UNIT	RECOMMENDED PRESENTATION TIME (HOURS)
Overview	1	4	3
Elements of Troubleshooting	2	2	1 1/2
Sewer Use Control	3	2	1 3/4
Pre/Primary Treatment	4	2	1 3/4
Fixed Media Systems	5	2	2 1/4
Oxidation Lagoons	6	2	2 1/2
Laboratory Practices	7	3	2
Flow Measurement	8	2	1
Chemical Additions	9	2	2
Management Behavior	10	3	3 1/3
Activated Sludge	11	14	13 1/2
Solids Handling	12	5	5 2/3
Land Treatment	13	2	2
Disinfection	14	2	1
Closing	15	2	1
Total	15	49	44 1/4

The Units of Instruction are numbered sequentially from 1 to 15. In a typical course the Units of Instruction are presented in numerical sequence which follows the waste flow pattern from influent to effluent. In more resent presentations of the course, the course developers have altered the sequencing of those Units of Instruction which relate to treatment processes and operations with no serious adverse effects on either course continuity or effectiveness.

B. *Adjusting Course Length*

A minimum of 44 1/4 training contact hours is required to present all materials contained in the instructional package. Additional time is needed for trainee breaks and lunch periods. Because of the total time required to present all training materials in the course package, the course developers have never presented the entire training package as a single course. The course developers have normally presented *Troubleshooting O & M Problems in Wastewater Treatment Facilities* as a five-day workshop and have limited the courses to 33-35 contact hours of instruction.

Several of the shorter Units of Instruction have been deleted from course presentations made by the course developers. Deletions are made to tailor the course to the needs of the trainees enrolled in a particular course. At various times, one or more of the Units of Instruction on *Pre/Primary Treatment*, *Fixed Media Systems*, *Oxidation Lagoons*, *Laboratory Practices*, *Flow Measurement*, *Chemical Additions*, *Land Treatment* and *Disinfection* have been deleted from particular course presentations. Such deletions have not detracted from the course or its effectiveness.

C. *The Minimum Course*

The course developers recommend that the following Units of Instruction be included in presentations of *Troubleshooting O & M Problems in Wastewater Treatment Facilities*:

Overview	Unit 1
Elements of Troubleshooting	Unit 2
Management Behavior	Unit 10
Activated Sludge	Unit 11
Solids Handling	Unit 12
Closing	Unit 15

Of course, if a particular presentation of the training materials is targeted toward trainees who are primarily interested in *Oxidation Lagoons* or *Fixed Media Systems*, substitution of these Units of Instruction for the *Activated Sludge* unit would be appropriate. It may also be appropriate to tailor the other units of instruction to reflect the specific needs of trainees involved with less complex treatment systems.

The *Overview* and *Elements of Troubleshooting* Units of Instruction set the tone and direction for the course. They initiate trainee interaction early in the course sequence by using a teaching technique based on game playing. Therefore, these Units of Instruction should always be the first units presented in any course based on the *Troubleshooting O & M Problems in Wastewater Treatment Facilities* training materials. The *Management Behavior* unit directs the trainee's attention to "people" problems rather than "things" problems and is applicable to all training programs directed toward improving problem solving skills.

D. *Alternate Presentation Formats*

The course developers and others have used the *Troubleshooting O & M Problems in Wastewater Treatment Facilities* training materials in a variety of delivery formats. As indicated earlier, the five-day workshop has been the most common format. The developers have presented the course as a sequence of one-day workshops spaced one to two weeks apart with good success. The course has also been presented in an evening class format with presentations made as a series of 11-15 three or four hour sessions during an academic quarter or semester. Other presentations have been made which presented only one unit operation or process in a one-day workshop.

The training materials have proven to be an extremely flexible resource for developing numerous derivative courses. The developers have used Units of Instruction or selected lessons from Units of Instruction as supplemental materials in many operator training programs.

When using alternate delivery formats, caution must be exercised to structure the course into logical instructional units so that course continuity is not lost. This may require that individual Units of Instruction be expanded or contracted to meet the constraints imposed by the delivery format.

E. *Designing Your Course*

The Course Director must first decide which of the fifteen (15) Units of Instruction will be taught. Factors, such as number and types of treatment plants in a geographic or political region, the number of potential trainees, interests of the potential trainees, educational and work backgrounds of potential trainees, employer needs and time available for the course, must be considered in deciding which Units of Instruction to include in the course.

Next the Course Director must decide how much time will be devoted to each wastewater treatment process, operation or activity. The depth of coverage desired will be the primary determinant in allocating time to each Unit of Instruction. The Recommended Times listed in Table I are the contact hours required to present each Unit of Instruction in its entirety as presented in the lesson plans. The Recommended Times do not include "break" periods. Each Unit of Instruction may be expanded, contracted or deleted depending on the needs of the trainees. Although not recommended, some Units of Instruction could be significantly shortened by presentation as straight lectures and limiting the time for problem solving and discussion. The learning benefit from such an approach is questionable but may be acceptable if the course objective is limited to a quick review of an unit operation or unit process.

The Course Director must define the objectives for a particular course, review each Unit of Instruction carefully, edit the Unit of Instruction as necessary to meet his/her course objectives and then allocate the time to be devoted to the Unit of Instruction. *Appendix* C summarizes the objectives, content, approach and training materials for each of the 15 Units of Instruction.

Now, the Course Director can set the agenda for the course and begin recruiting trainees.

VII. *Instructors*

The four most important criteria in the selection of instructors for this course are a) knowledge of the treatment process being taught, b) practical experience operating a facility using that treatment plant process, c) diversified experience evaluating and troubleshooting wastewater treatment plants, and d) experience (and ability) to instruct adults using less traditional materials and techniques. In addition the Course Director should select instructors whom he believes have a positive attitude toward the *Process of Troubleshooting* and can relate to the people problems as well as the technical problems which contribute to poor plant performance.

Before any instructor is permitted to go before a class, the Course Director should schedule a briefing and preparation session in which a brief review of the overall course, and more specifically the lesson objectives, takes place. Through discussion, there should be an assurance that the instructor is well-prepared and comfortable with the material and techniques which he/she will be using. Many instructors prefer to use case history problems drawn from their own experience. The Course Director should make sure that the examples used by the instructor support the course and lesson objectives.

The Course Director should stress the difference in the role that the instructor may play during the presentation of his/her particular materials. For example, he or she may be the content resource person at the initial part of the lesson and shift to the role of an educational manager during a group problem solving session.

It is particularly helpful if instructors are able to sit in on earlier sessions of the course, particularly the sessions on *Overview* and *Elements of Troubleshooting*, so that they get a "feel" for the way the trainees are oriented toward the material. Having the instructors play the board game during the *Overview* session is an excellent orientation for them.

Preparation must be stressed to all prospective instructors. Even though course materials are thoroughly prepared, even "expert" instructors need some practice in presenting some of the techniques built into the lesson plans.

VIII. *Physical Settling and Group Activities*

This course is designed with a variety of group activities and group work as a part of the instructional process. This means that the Course Director, in considering the physical setting for the course, needs to anticipate facilities which will accommodate the class in groups of four at tables and chairs, as well as auxiliary facilities for "break out" sessions. For example, since the course is designed to use groups of four, a class of 28 or 32 (multiples of four) would be a maximum number to accommodate in most education and training facilities of approximately 40 ft by 40 ft square. This would allow room for a 8 ft x 10 ft or a 10 ft x 10 ft screen in the front of the room, a table-top lecturn with a light, an easel, a pointer, a bar stool, a chalkboard and other paraphernalia and equipment to be located in the front of the room.

Set in a "herring-bone" design or U shaped configuration, so that most of each group of four are facing forward when necessary (but can move around to face each other at their particular groups and tables in the work group), the room should also be equipped with a 35mm carousel-type automatic projector with a remote control switch extending to the table-top lecturn, an overhead projector and a few extra chairs spaced at random around the back, side and speaker's area of the room.

In addition to the main meeting room, the Course Director should give preference to a separate room, set with card tables and chairs for use in the Board Game (Unit 1, *Overview*) and three additional break out rooms (or a total of five rooms including the main classroom) so that the break out rooms can be set for the "fish bowl" role playing exercises called for in the *Solids Handling* (Unit 12).

As soon as a complete registration list of trainees is available (usually not until the first day of the course), the Course Director should set up 4-person trainee groups. Groups should be well balanced, among persons (if possible) who are new to each other. For example, if enrollment in the course is half engineers, half biologists, some of each should be in each group. If the trainees are comprised of persons from the same offices, attendees from each office should be dispersed among several groups so that each trainee can come in contact with "new" people from whom he/she can learn. Persons with similar educational and work experience backgrounds should not be assigned to the same work group.

Trainee groups are first used in the Board Game portion of the *Overview* unit. For the remainder of the course, groups should be seated together, inasmuch as they must frequently participate in group learning activities. The Course Director should place signs showing work group number at each table to aid trainees in locating their seats.

IX. *Use and Preparation of Materials*

Attached to the 15 Units of Instruction in this course is a second volume which is identified as the *Trainee Notebook.* This contains all the materials the trainees will need for the entire course subdivided into fifteen sections from *Overview* to *Disinfection.* The materials in the *Trainee Notebook* will need to be reproduced in multiples to equal that of the number of trainees the Course Director anticipates attending the course. Naturally, if certain Units of Instruction and/or lessons of the course are not being included (for example, if *Disinfection* is not to be taught) then everything but that trainee section (*Disinfection*) would be reproduced for the course. Likewise, if a particular unit is being taught in and by itself (for example, *Troubleshooting* and *Oxidation Lagoons*) then the *Trainee Notebook* materials for the *Overview*, the *Elements of Troubleshooting*, and *Oxidation Lagoons* would be reproduced for the total number of students anticipated.

Since many of the lessons make reference to sections in the USEPA's manual entitled *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, copies of this manual should be made available to each member and instructor participating in the course. Care should be taken to obtain these from USEPA or the Government Printing Office, or reproduce them en masse well in advance of the course. A lead time of six months is not unreasonable when ordering materials from the Government Printing Office.

Additional materials need to be acquired for the *Activated Sludge* Unit. Copies of Part I and II of the pamphlets *Operator's Pocket Guide to Activated Sludge* should be distributed to each trainee. In addition, the pamphlet series on operational control of activated sludge prepared by Alfred W. West of the National Training and Operational Technology Center, U.S. Environmental Protection Agency are needed.

Several units have specific materials which will need to be duplicated for handing out at appropriate times during the course. A complete listing of the materials to be duplicated for the course is included in *Appendix* A which is located at the end of this section. *Appendix* B lists the materials which are commercially available and must be ordered for the course.

Recognizing that instructors will modify and supplement the training materials, all text has been prepared as photoready typewritten copy. IBM Selectric with a Letter Gothic - 12 pitch type face was used. All italic inserts are with IBM Selectric Script - 12 pitch type face.

X. *Unit Plan Use and Mechanics*

Each Unit Plan module should serve as a self-contained set of:

A. Instructions to the instructor
B. Lesson outlines
C. Visual aids
D. *Trainee Notebook* materials
E. Handout and other materials
F. Guidelines on the approach to the Unit

Each Unit contains a section on Presentation Options to the Course Director. These should be reviewed while the course is in the planning stage because some of the options could affect the scheduling of the Course. There should be agreement between the Course Director and the instructor for any given lesson before major changes are made.

Each Unit plan outline is carefully timed. Instructors should be cautioned to observe the time schedules, and to become familiar with the "pace" of the lesson he/she is to give.

Instructors must become familiar with the visual aid and *Trainee Notebook* materials before attempting to present a Unit of Instruction.

There is no reason why instructors cannot vary from the format or content of any given Unit of Instruction as long as the *course, unit and lesson objectives* are achieved. However, variations should be in the direction of *greater trainee participation*. It is strongly recommended that no changes which decrease trainee participation be permitted.

XI. *Format of the Instructor Notebook and Trainee Notebook Materials*

As stated earlier the *Instructor Notebook* and *Trainee Notebook* are presented as fifteen modules called Units of Instruction. *Appendix* A lists all training aids included in the *Instructor Notebook*, including handouts which are distributed to trainees by the instructor at the appropriate points in the course presentation, and *Trainee Notebook* materials. *Trainee Notebook* materials and handouts must be locally reproduced. *Appendix* B lists trainee materials which must be purchased.

A. *Instructor Notebook*

The *Instructor Notebook* contains lesson plans and all printed materials needed to present the course. The instructor materials for each Unit of Instruction are organized as follows:

1. Instructor Overview of the Unit

The Instructor Overview of the Unit provides a summary of all learning activities which occur in the unit and pre-course preparation which is required to present the Unit. Figure 1, page xix illustrates the format and content of the Instructor Overview materials.

Pages in the Instructor Overview of the Unit are numbered *X.Y* where *X* is the unit number and *Y* is the page sequence number.

2. Lesson Plan

Detailed lesson plans are located immediately following the Instructor Overview of the Unit in the *Instructor Notebook*. The lesson plans document the materials, presentation techniques, procedures and sequencing which the course developers found to be effective. The initial pages of the lesson plan provide summary information necessary to prepare for the lesson presentation. Figure 2, page xx, illustrates the typical lesson plan format and summarizes its content. Lesson plan outlines are presented in a modified "story-board" format.

Lesson plan pages are numbered *X.Y.Z* where *X* is the unit number, *Y* is the lesson number and *Z* is the page sequence number.

3. Trainee Materials

All materials which appear in the *Trainee Notebook* or which are to be reproduced as trainee handouts are located after the lesson plans in the *Instructor Notebook*.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction:

Unit ___ of 15 Units of Instruction

Lessons in Unit: ___ Recommended Time: __ hours

Instructor Overview of the Unit

Rationale for Unit:

Trainee Entry Level Behavior:

Trainee Learning Objective:

Sequencing and Pre-Course Preparation for the Unit:

Lesson __:

Recommended Time:

Purpose:

Training Facilities:

Pre-Course Preparation:

Instructor Approach:

Lesson __: (as above)

Presentation Options for the Course Director:

Summary of Unit of Instruction __:
(Tabular recap of Unit Features)

Figure 1. Example Format for Instructor Overview of the Unit

TROUBLESHOOTING O & M PROBLEMS IN
WASTEWATER TREATMENT FACILITIES

Unit of Instruction:

Lesson ___:

Lesson ___ of ___ Recommended Time:

Purpose:

Trainee Entry Level Behavior:

Trainee Learning Objectives:

Instructional Approach:

Lesson Schedule:

Trainee Materials Used in Lesson:

Instructor Materials Used in Lesson:

Instructor Materials Recommended for Development:

Additional Instructor References:

Classroom Set-Up:

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

Figure 2. Example Format for Lesson Plan

a. Trainee Notebook Materials

All pages which are reproduced and included in the *Trainee Notebook* to support the Unit of Instruction are included in the *Instructor Notebook* and numbered as *Tx.y.z* where *T* is a letter prefix for *Trainee Notebook* page, x is the unit number, *y* is the lesson number and z is the page sequence.

b. Trainee Handouts

All pages which are to be reproduced and distributed by the instructor as they are needed in the unit are also included in the *Instructor Notebook* and numbered as *Hx.y.z* where *H* is a letter prefix for trainee handout, x is the unit number, *y* is the lesson number and z is the page sequence.

4. Visual Aids

The final component of the *Instructor Notebook* is the visual aids package. All visual aids are offered in 35mm slide format. The slides are numbered to correspond to the Unit of Instruction and lesson number within the unit. The numbering system is *179.2/X.Y.Z* where *179.2* is the course number assigned by EPA, NTOTC to *Troubleshooting O & M Problems in Wastewater Treatment Facilities*, *X* and *Y* are the numbers of the Unit of Instruction and the lesson, respectively, in which the slide is used, and *Z* is the slide sequence number.

The slide set includes some black or blank slides. These are inserted in the sequence to blacken the screen and clue the instructor when another form of training aid is to be used or when the lights need to go on so that trainees may refer to printed materials. These are included strictly as a convenience to the instructor if he/she does not have a capability to turn the project on or off with the remote controls at the lectern.

The slides are sequenced so that the instructor is not required to back-up or reshuffle slides as they are used in the lesson plans. Thus some slides are duplicates of predecessor slides in the set.

The use of a single media, 35mm slides, throughout a five-day short course tends to give the trainees the impression that the course is rigidly structured and may inhibit discussion. As an option to the Course Director, the developers have provided printed masters of some title slides. These may be used to make thermal overhead transparencies and provide a media option which some instructors may prefer. The availability of the print master is noted in the lesson plan. The print master is numbered identically to the slide which it may replace. Therefore the numbering of the print masters is not sequential.

B. *Trainee Notebook*

Although the *Trainee Notebook* materials are included in their entirety in the *Instructor Notebook*, these materials are separately collated and bound as a convenience to the Course Director. The *Trainee Notebook* is not commercially available and must be reproduced locally.

Commercially available materials which are to be provided to the trainees are not reproduced in the *Trainee Notebook*.

The course developers and the EPA recognize that some *Trainee Notebook* sections will require periodic modification to update materials or to incorporate materials specific to the needs of a user of the course materials. Therefore, all course specific printed materials are available as photo-ready typewriter copy. All materials were typed using an IBM Selectric Letter Gothic, 12 pitch type face. Italic inserts are with the IBM Selectric Script, 12 pitch type face.

XII. *Availability of Training Materials*

Arrangements to obtain copies of all materials to present *Troubleshooting O & M Problems in Wastewater Treatment Facilities* can be made by contacting:

National Training and Operational Technology Center
ATTN: Course 179.2 Coordinator
U.S. Environmental Protection Agency
26 West St. Clair Street
Cincinnati, OH 45268

XIII. *Other Logistics*

Since the Course Director will need to consider a variety of logistics, depending upon the format, location and participants of the course, the attached checklist, *Appendix D*, will serve as a suggested checklist of special items to consider.

Again, the course developers have provided you with these guidelines so that you would be aware of our thinking and planning throughout the development of the course. We hope that this information will be helpful to you in your plans for conducting what we consider to be a unique and exciting educational venture.

Good luck and best wishes.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Guidelines for the Course Director

APPENDICES

Appendix A: Inventory of Training Materials A-1

Appendix B: Training Materials to be Ordered B-1

Appendix C: Summary of Course C-1

Appendix D: Checklist of Activities for Presenting the Course D-1

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Guidelines for the Course Director

APPENDIX A

Inventory of Training Materials

UNIT	TITLE	LESSON	INSTRUCTIONAL MATERIALS	TRAINEE NOTEBOOK* MATERIALS	HANDOUT* MATERIALS	SLIDES
1	Overview	1	1.1.1-1.1.7	T1.1.1-T1.1.2	-	-
		2	1.2.1-1.2.8	-	H1.2.1-H1.2.16	-
		3	1.3.1-1.3.22	T1.3.1-T1.3.5	-	179.2/1.3.1-179.2/1.3.4
		4	1.4.1-1.4.13	-	-	-
			Game Materials			
2	Elements of Troubleshooting	1	2.1.1-2.1.19a	T2.1.1-T2.1.2	-	179.2/2.1.1-179.2/2.1.9
		2	2.2.1-2.2.28	T2.2.1-T2.2.12	-	179.2/2.2.1-179.2/2.2.17
3	Sewer Use Control	1	3.1.1-3.1.15	-	H3.1.1-H3.1.10	-
		2	3.2.1-3.2.23	T3.2.1-T3.2.29	-	179.2/3.2.1-179.2/3.2.13
4	Pre/Primary Treatment	1	4.1.1-4.1.17	T4.1.1-T4.1.24	-	179.2/4.1.1-179.2/4.1.34
		2	4.2.1-4.2.16	T4.2.1-T4.2.3	-	179.2/4.2.1-179.2/4.2.34
5	Fixed Media Biological Systems	1	5.1.1-5.1.16	T5.1.1	-	179.2/5.1.1-179.2/5.1.31
		2	5.2.1-5.2.14	T5.2.1-T5.2.8	-	179.2/5.2.1-189.2/5.2.19
6	Oxidation Lagoons	1	6.1.1-6.1.16	T6.1.1-T6.1.2	-	179.2/6.1.1-179.2/6.1.47
		2	6.2.1-6.2.7	T6.2.1-T6.2.7	-	-
7	Laboratory Practices	1	7.1.1-7.1.14	-	-	179.2/7.1.1-179.2/7.1.9
		2	7.2.1-7.2.20	T7.2.1	-	179.2/7.2.1-179.2/7.2.29
		3	7.3.1-7.3.6	T7.3.1	-	179.2/7.3.1-179.2/7.3.26

*Must be reproduced locally

APPENDIX A

Inventory of Training Materials (Continued)

UNIT	TITLE	LESSON	INSTRUCTIONAL MATERIALS	TRAINEE NOTEBOOK* MATERIALS	HANDOUT* MATERIALS	SLIDES
8	Flow Measurement	1	8.1.1-8.1.7	T8.1.1-T8.1.3	-	179.2/8.1.1-179.2/8.1.6
		2	8.2.1-8.2.14	T8.2.1-T8.2.3	-	179.2/8.2.1-179.2/8.2.27
9	Chemical Additions	1	9.1.1-9.1.18	T9.1.1-T9.1.5	-	179.2/9.1.1-179.2/9.1.32
		2	9.2.1-9.2.8	T9.2.1	-	179.2/9.2.1-179.2/9.2.9
10	Management Behavior	1	10.1.1-10.1.10	T10.1.1-T10.1.2	-	179.2/10.1.1-179.2/10.1.3
		2	10.2.1-10.2.12	T10.2.1-T10.2.25	-	179.2/10.2.1-179.2/10.2.13
		3	10.3.1-10.3.5	T10.3.1-T10.3.12	-	-
11	Activated Sludge	1	11.1.1-11.1.44	T11.1.1	-	179.2/11.1.1-179.2/11.1.20
		2	11.2.1-11.2.40	T11.2.1-T11.2.28	-	179.2/11.2.1-179.2/11.2.15
		3	11.3.1-11.3.9	T11.3.1	-	179.2/11.3.1-179.2/11.3.6
		4	11.4.1-11.4.11	T11.3.1-T11.4.2	-	179.2/11.4.1-179.2/11.4.22
		5	11.5.1-11.5.27	T11.5.1-T11.5.8	-	179.2/11.5.1-179.2/11.5.29
		6	11.6.1-11.6.27	T11.6.1-T11.6.9	-	179.2/11.6.1-179.2/11.6.49
		7	11.7.1-11.7.9	T11.7.1-T11.7.11	H11.7.1-H11.7.37	-
		8	11.8.1-11.8.25	-	-	179.2/11.8.1-179.2/11.8.67
		9	11.9.1-11.9.6	T11.9.1-T11.9.8	-	-
		10	11.10.1-11.10.6	-	H11.10.1-H11.10.11	179.2/11.10.1-179.2/11.10.8
		11	11.11.1-11.11.7	T11.11.1-T11.11.6	-	179.2/11.11.1-179.2/11.11.23
		12	11.12.1-11.12.47	T11.12.1-T11.12.16	-	179.2/11.12.1-179.2/11.12.54
		13	11.13.1-11.13.11	-	-	179.2/11.13.1-179.2/11.13.28
		14	11.14.1-11.14.21	T11.14.1-T11.14.3	-	179.2/11.14.1-179.2/11.14.7

*Must be reproduced locally

APPENDIX A

Inventory of Training Materials (Continued)

UNIT	TITLE	LESSON	INSTRUCTIONAL* MATERIALS	TRAINEE NOTEBOOK MATERIALS	HANDOUT* MATERIALS	SLIDES
12	Solids Handling	1	12.1.1-12.1.28	T12.1.1-T12.1.4	-	179.2/12.1.1-179.2/1.12.34
		2	12.2.1-12.2.11	T12.1.1-T12.2.2	H12.1.1-H12.1.5	
		3	12.3.1-12.3.32	T12.3.1-T12.3.11	-	179.2/12.3.1-179.2/12.3.53
		4	12.4.1-12.4.3	-	-	-
		5	12.5.1-12.5.7	T12.5.1	-	-
13	Land Treatment	1	13.1.1-13.1.24	T13.1.1	-	179.2/13.1.1-179.2/13.1.40
		2	13.2.1-13.2.9	T13.1.1-T13.1.10	-	179.2/13.2.1-179.2/13.2.12
14	Disinfection	1	14.1.1-14.1.14	-	-	179.2/14.1.1-179.2/14.1.18
		2	14.2.1-14.2.8 Process of Troubleshooting Wall Chart	T14.2.1	-	179.2/14.2.1-179.2/14.2.8
15	Closing	1	15.1.1-15.1.6	-	-	-
		2	15.2.1-15.2.12	-	-	-

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Guidelines for the Course Director

APPENDIX B

Training Materials to be Ordered

1. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA-430/9-78-001, Municipal Operations Branch, Office of Water Program Operation, U. S. Environmental Protection Agency, Washington, D.C. 20460 (January, 1978).

2. *Operators Pocket Guide to Activated Sludge, Part I: The Basics* and *Part II: Process Control and Troubleshooting*, STRAAM Engineers, Inc., 5505 S. E. Milaukie, Portland, Oregon 97202 (1975).

3. West, A. W., *Operational Control Procedures for the Activated Sludge Process*, Parts I, II, IIIA, IIIB and Appendix, National Training and Operational Technology Center, U. S. Environmental Protection Agency, Cincinnati, Ohio 45268.

4. West, A. W., "Updated Summary of the Operational Control Procedures for the Activated Sludge Process," National Training and Operational Technology Center, U. S. Environmental Protection Agency, Cincinnati, Ohio 45268 (January, 1978).

5. West, A. W., "Dynamic Sludge Age," National Training and Operational Technology Center, U. S. Environmental Protection Agency, Cincinnati, Ohio 45268 (1979).

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Guidelines for the Course Director

APPENDIX C

Summary of Course

SUMMARY OF UNIT OF INSTRUCTION 1: *OVERVIEW*

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS & CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Welcome, Introduction & Orientation 30 minutes	1. Familiarize trainees with purpose and nature of course.	1. Introduction of students and faculty.	1. Follow lesson outline. 2. Be informed. 3. Make trainees feel comfortable.	1. *Trainee Notebook* (see *Guidelines for the Course Director*, Appendix A and B). 2. *Field Manual for Perforamnce Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilitie*
2. Trainee Assessment 30 minutes	1. Assess trainee knowledge of treatment plant operations.	1. Exam on various facets of treatment plant operations.	1. Instructor supervises exam. 2. Instructor present to answer questions.	1. Trainee assessment exam. 2. Answer sheet 3. Answer key
3. The Significance of Plant O & M 30 minutes	1. Relate technical assistance and troubleshooting O & M problems to attainment of water pollution control program goals.	1. Importance of a balanced regulatory/assistance approach to controlling municipal discharges.	1. Follow lesson plan outline, using slides and key. 2. Trainee discussion at appropriate points	1. Lesson plan with selected slides 2. *Trainee Notebook*,

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS & CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
	2. Identify factors which affect the performance of treatment plants.	2. Magnitude & scope of O & M problem. 3. Survey results which document factors affecting plant performance.	3. Reference to *Trainee Notebook*	
4. Evaluating Treatment Plant Operations: A Board Game. 90 minutes	1. Breakdown trainee work group communication inhibitions. 2. Orient trainees to typical O & M problems in treatment plants. 3. Involve trainees in problem solving.	1. Broad overview of course. 2. Working relationship between members of trainee groups. 3. Treatment plant problem solving 4. Troubleshooting as a process to solve complex problems.	Instructor supervises four stages to game. 1. Preparation 2. Instructions and initiation of play. 3. Play 4. Conclusion of play	Complete sets of game materials for each trainee work group.

Summary of Unit of Instruction 2: *Elements of Troubleshooting*

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Attitudes and Human Behavior in Troubleshooting 45 minutes	1. Define troubleshooting. 2. Relate human behavior aspects of troubleshooting to the trainees' jobs. 3. Discuss the role of troubleshooters in relation to plant operators. 4. Differentiate between human and technical skills. 5. Compare positive and negative types of troubleshooter behavior.	1. Human attitudes and behavior in troubleshooting. 2. Analysis of type of troubleshooter behavior. 3. Good characteristics of troubleshooter behavior.	1. Use outline and slides, maximize class discussion. 2. Present two troubleshooting dialogues. 3. Analyze two troubleshooting dialogues with class discussion. 4. Discuss troubleshooter behavior, using chalkboard to record input.	1. Slide series and key. 2. Troubleshooting dialogues No. 1 and No. 2, scripts. 3. *Trainee Notebook* pages T2.1.1 - T2.1.2.
2. The Process of Troubleshooting 45 minutes	1. List the basic elements of troubleshooting. 2. Use the chart, the *Process of Troubleshooting*.	1. The importance of a systematic approach. 2. The basic elements of troubleshooting.	1. Use outline and slide key. 2. Maximize student discussion and involvement.	1. Slide series and key. 2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities.*

Summary of Unit of Instruction 2: *Elements of Troubleshooting* (continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
	3. Locate and identify useful information.	3. Troubleshooting Chart steps and elements in the *Process of Troubleshooting.*		3. Inspection checklist, *Trainee Notebook,* pages T2.2.1 - T2.2.7.
	4. Approach plant problems by formulating alternative solutions.	4. The importance of alternatives.		4. Charts, the *Process of Troubleshooting, Trainee Notebook,* page T2.2.8 - T2.2.10
	5. List criteria for effective technical assistance.	5. Importance of final troubleshooting steps.		5. *Trainee Notebook,* pages T2.2.11 - T2.2.12.
		6. Criteria for effective technical assistance.		

Summary of Unit of Instruction 3: *Sewer Use Control*

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Applying the Process of Troubleshooting	1. Apply the Process of Troubleshooting	1. The Process of Troubleshooting	1. Present two problems to class in three stages	1. *Instructor Notebook*, pages H3.1.1-H3.1.6
60 minutes	2. Analyze treatment problems caused by collection system	2. Collection system effects on treatment facility performance	2. Guide trainees during problem solving	2. *Instructor Notebook*, pages H3.1.7-H3.1.10
		3. Problem solving in teams	3. Lead class discussion of findings	3. *Trainee Notebook*, page 2.2.8
			4. Distribute problem solutions	
2. Sewer Use Control and Industrial Waste Monitoring 45 minutes	1. Identify effects of collection system on treatment facility performance	1. Importance of sewer use control to treatment facility performance.	1. Follow Lesson Outline using slides and key	1. Slides 179.2/3.2.1-179.2/3.2.13
	2. Give criteria for evaluating collection system	2. Requirements for industrial pretreatment and waste monitoring	2. Trainee discussion at appropriate points	2. *Trainee Notebook*, pages 3.2.1 - 3.2.29.
	3. Review EPA regulations on pretreatment & industrial waste monitoring	3. Contents of sewer use ordinance	3. Reference to *Trainee Notebook*	
	4. Assist in preparing and enforcing sewer use ordinance	4. Sources of information on collection system O & M		

Summary of Unit of Instruction 4: Pre/Primary Treatment

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Preliminary Treatment 55 minutes	1. Recognize importance of preliminary treatment	1. Preliminary Treatment purposes and functions	1. Trainee problem solving and discussion	1. *Trainee Notebook* pages T4.1.1 - T4.1.24.
	2. Identify preliminary treatment problems	2. Uses of flow equalization	2. Illustrated lecture using lesson outline and slides	2. *Instructor Notebook*, pages 4.1.1 - 4.1.17.
	3. Apply visual observations to problem identification	3. Typical preliminary treatment problems		3. Slides 179.2/4.1.1 - 179.2/4.1.34.
	4. Practice the Process of Troubleshooting	4. Observations to make in preliminary treatment processes		
2. Primary Treatment 50 minutes	1. Apply the Process of Troubleshooting to Primary Treatment	1. Steps in the process of troubleshooting	1. Illustrated lecture using lesson outline and slides	1. *Trainee Notebook* pages T4.2.1 - T4.2.3.
	2. Identify common problems in primary treatment	2. Data needed to evaluate primary treatment	2. Class discussion	2. *Instructor Notebook*, pages 4.2.1 - 4.2.16.
		3. Common problems in primary treatment operations		3. Slides 179.2/4.2.1 - 179.2/4.2.34.

Summary of Unit of Instruction 5: Fixed Media Biological Systems

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Troubleshooting Fixed Media Biological Systems	1. Describe fixed media system factors and performance	1. Basic properties and expected performance of fixed media systems	1. Follow lesson outline	1. Slides 179.2/5.1.1-179.2/5.1.31
40 minutes	2. Identify appropriate steps in the Process of Troubleshooting	2. Importance of troubleshooter behavior	2. Rely upon slide series and lesson plans	2. Process of Troubleshooting Chart, *Trainee Notebook*, page T2.2.8
	3. Identify things to observe, records to review and process control tests for troubleshooting	3. Importance of daily log, observations and records		3. *Instructor Notebook*, pages 5.1.1 - 5.1.16
	4. List common operating problems and their causes	4. Importance of testing		4. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*
	5. Recognize problems in small plants	5. Special problems in dealing with small plants		5. *Trainee Notebook*, page T5.1.1

Summary of Unit of Instruction 5: Fixed Media Biological Systems (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
2. Applying the Process of Troubleshooting 90 minutes	1. Follow systematic approach to solving trickling filter problems	1. Four operational problems for student groups to identify and develop solutions	1. Trainees work in groups	1. Answer sheets, *Trainee Notebook*, pages T5.2.1 - T5.2.7
	2. Identify problems and their causes	2. Approach to ventilating trickling filters	2. Instructor presents problems with a brief description and slides	2. Slides 179.2/5.2.1 - 179.2/5.2.10
	3. List effects and symptoms of trickling filter problems	3. Troubleshooting small plants with part-time operators	3. Groups, through discussion, have 10 minutes to solve each problem as to identify, cause, effects, proposed correction	3. *Instructor Notebook*, pages 5.2.1 - 5.2.8
	4. Determine methods of correction for operating problems	4. Maintaining good distribution over filters	4. Group leaders present approaches to problems	4. Answer sheets, *Trainee Notebook*, pages T5.2.1-T5.2.7
	5. Compare approaches to solving trickling filter problems	5. Correcting ponding problems	5. Repeat slide depicting problems	5. Slides 179.2/5.2.11 - 179.2/5.2.19
	6. Evaluate problem approaches to the instructor's suggested solutions		6. Instructor stimulates discussion on groups' approaches	6. *Instructor Notebook*, pages 5.2.9 - 5.2.14
	7. Consider the merits of alternative approaches to trickling filter problems			7. *Trainee Notebook*, page T5.2.8, "References"

Summary of Unit of Instruction 6: Oxidation Lagoons

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
1. Troubleshooting Oxidation Lagoons	1. Describe lagoon properties and characteristics	1. Lagoon characteristics	1. Follow subject outline	1. Slides 179.2/6.1.1 - 179.2/6.1.47
60 minutes	2. Recognize and identify lagoon problems	2. Trouble indicators	2. Use prepared slide series	2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 100 - 109
	3. List problem causes	3. Tests and analyses	3. Seek student input in following outline	3. *Trainee Notebook*, pages T6.1.1 - T6.1.2
	4. Know corrective actions for lagoon problems	4. Troubleshooting Guide		4. *Instructor Notebook*, pages 6.1.1 - 6.1.16
	5. Identify means of upgrading lagoons	5. Methods of upgrading lagoons		
2. Applying the Process of Troubleshooting 90 minutes	1. Follow systematic approach to solving lagoon problems	1. Students are presented a realistic problem in lagoon operation which they must approach, think through and solve	The assigned problem has three stages in which the students must: 1. Decide how to approach the problem.	1. *Trainee Notebook*, pages T6.2.1 - T6.2.6, "Problem Answer Sheets"

Summary of Unit of Instruction 6: Oxidation Lagoons (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
	2. Determine trouble-shooting data, nature of problem and likely cause.	2. Stress the systematic approach to troubleshooting lagoon problems	2. Determine what the problem is	2. *Instructor Notebook*, pages 6.2.1 - 6.2.7
	3. Recommend actions to correct lagoon operating problem	3. Stress the need to talk and work with people on solving problems	3. Recommend problem corrections. Trainees work in predetermined groups	3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 100 - 109
	4. Compare approaches to assigned problem, and consider the merits of alternative approaches		4. Maximum student discussion of problem assigned in Lesson 2. Lesson outline provided to guide class discussion	

Summary of Unit of Instruction 7: Laboratory Practices

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
1. The Laboratory as a Tool for Process Control and Troubleshooting 30 minutes	1. Describe lab uses for process control and troubleshooting	1. Process of Troubleshooting requires good lab analysis	1. Follow lesson outline using slides and key	1. Process of Troubleshooting Chart, *Trainee Notebook*, page T2.2.8
	2. Utilize sampling procedures	2. Inadequate labs have caused poor process control	2. Encourage student discussion	2. *Instructor Notebook*, pages 7.1.1 - 7.1.14
	3. Evaluate treatment	3. Troubleshooters need to know proper sampling procedures	3. Continually focus on the value of the lab for troubleshooting and process control	3. Slides 179.2/7.1.1 - 179.2/7.1.9
2. Troubleshooting Laboratory Practices 60 minutes	1. Identify and evaluate factors of lab adequacy	1. Three factors which identify lab adequacy	1. Follow lesson outline, using slides and key, and *Notebook* materials	1. Slides 179.2/7.2.1 - 179.2/7.2.29
	2. Evaluate lab staffing and procedures	2. Lab staff and procedures can be upgraded	2. Slide series should stress involvement of students in identifying the significance of what is seen on slides	2. *Trainee Notebook*, page T7.2.1
	3. Evaluate lab equipment, facilities and housekeeping	3. Lab housekeeping, maintenance and safety precautions are important indicators of lab adequacy		3. *Instructor Notebook*, pages 7.2.1 - 7.2.20

Summary of Unit of Instruction 7: Laboratory Practices (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
	4. Identify and prevent safety hazards 5. Approach lab troubleshooting constructively to overcome barriers	4. Troubleshooter attitude and behavior is important toward overcoming troubleshooting barriers		
3. Laboratory Equipment 30 minutes	1. To identify commonly used laboratory equipment 2. To identify favorable and unfavorable lab conditions	1. Specific laboratory equipment	1. Use slides and slide key-full discussion	1. *Instructor Notebook*, pages 7.3.1 - 7.3.6 2. Slides 179.2/7.3.1 - 179.2/7.3.26 3. *Trainee Notebook*, page T7.3.1

Summary of Unit of Instruction 8: Flow Measurement

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
1. Flow Measurement and Treatment Plant Operation	1. List purposes of flow measurement and types of flows	1. Flow measurement purposes	1. Follow subject outline with slide series	1. Slides 179.2/8.1.1 - 179.2/8.1.6
30 minutes	2. Identify relationship of knowledge of flows to plant operations	2. Types of flows	2. Trainee group exercise using work sheets & flow diagram	2. "Trainee group work sheet and flow diagram," *Trainee Notebook*, pages T8.1.1-T8.1.3
	3. Characterize flows as linkages between plant processes that comprise the overall waste treatment system.			3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pp. 256-263
2. Troubleshooting Treatment Plant Flow Measurement	1. Identify flow measurement devices	1. Process of troubleshooting	1. Follow subject outline with slide series	1. Slides 179.2/8.2.1 - 179.2/8.2.27
30 minutes	2. Recognize common flow measurement problems	2. Poor flow measurements can create plant operating problems	2. Encourage trainee discussion and participation.	2. *Trainee Notebook*, pp. T8.2.1 - T8.2.3, "Troubleshooting Guide and Flow Equations"
	3. Describe troubleshooting procedures for flow measurement problems	3. Flow measurement devices and common problems	3. Use troubleshooting guide by referring to *Trainee Notebook*	3. Process of Troubleshooting Chart, *Trainee Notebook*, page T2.2.8

Summary of Unit of Instruction 8: Flow Measurement (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
	4. Identify field expidients for in-plant flow measurement	4. Systematic troubleshooting guide		4. *Instructor Notebook*, pages 8.2.1 - 8.2.14
		5. Expedients for flow measurment problem solving		5. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pp. 256-263

Summary of Unit of Instruction 9: Chemical Additions

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
1. Using Chemicals to Upgrade Treatment Plants 60 minutes	1. List and describe purposes and benefits of chemical additions	1. Purpose of chemical additions	1. Follow subject outline. Use prepared slide series.	1. Slides 179.2/9.1.1 - 179.2/9.1.32
	2. Describe tests, including jar tests, needed to determine proper chemicals and doses	2. Impact of chemical additions	2. Use *Trainee Notebook* materials at appropriate points in lesson	2. *Instructor Notebook*, pages 9.1.1 - 9.1.18
	3. Recognize factors in considering chemical additions	3. Determine proper chemicals and doses	3. Encourage student discussion and questions	3. *Trainee Notebook*, pages T9.1.1 - T9.1.5
	4. Know the impacts of chemical additions on a conventional plant	4. Factors considered in applying chemicals		4. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*
		5. Consequences on plant of chemical additives		
2. Troubleshooting Plants with Chemical Additions	1. List and identify trouble indicators in operations using chemical additions	1. Troubleshooters must be experienced with chemical additions if they are to assist	1. Follow subject outline. Use prepared slide series	1. Slides 179.2/9.2.1 - 179.2/9.2.9

Summary of Unit of Instruction 9: Chemical Additions (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
60 minutes	2. Know which observations and tests to use in troubleshooting chemical additions	2. The systematic Process of Troubleshooting is particularly important	2. Emphasize the Process of Troubleshooting	2. *Instructor Notebook*, pages 9.2.1 - 9.2.8
	3. Determine alternative corrections for problems with chemical additions	3. Troubleshooters must know the expected plant performance	3. Trainee discussion	3. Process of Troubleshooting Chart, *Trainee Notebook*, page T2.2.8
				4. *Trainee Notebook*, page T9.2.1, "References"
				5. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*

Summary of Unit of Instruction 10: Management Behavior

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
1. Management/ Administration and Treatment Plant Operations	1. Identify management deficiencies as a possible cause of poor plant performance	1. Management defects which can cause an O & M related problem	1. Trainee problem solving and discussion	1. *Trainee Notebook*, pages T10.1.1 - T10.1.2
60 minutes	2. Describe the relationship of management to O & M	2. Management's role in treatment plant operations	2. Illustrated lecture with discussion	2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pp. 295-314.
	3. Identify the troubleshooter's role in solving management related problems	3. The troubleshooters role in identifying management related problems	3. Recording information on chalkboard	3. *Instructor Notebook*, pages 10.1.1 - 10.1.10
				4. Slides 179.2/10.1.1-179.2/10.1.3
2. Troubleshooting Management Systems	1. Identify indicators of management related problems	1. Indicators of management problems	1. Illustrated lecture with trainee discussion	1. *Trainee Notebook*, pages T10.2.1 - T10.2.25
90 minutes	2. Define, compare and contrast management skills and management systems	2. Management skills and management systems	2. Frequent reference to *Trainee Notebook* materials	2. *Instructor Notebook*, pages 10.2.1 - 10.2.12

Summary of Unit of Instruction 10: Management Behavior (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
	3. Identify the components of a maintenance management system	3. Maintenance management system	3. Recording information on chalkboard	3. Slides 179.2/10.2 179.2/10.2.13
	4. Develop evaluation criteria for maintenance management systems	4. Maintenance management system evaluation checklist		
	5. Identify external factors which affect treatment plant management	5. External factors affecting treatment plant management		
3. Managerial Functions	1. Define management functions	1. Management functions	1. Illustrated lecture	1. *Trainee Notebook*, pages T10.3.1 - T10.3.12
50 minutes	2. Use the management audit checklist	2. Management Audit Checklist	2. Recording data on chalkboard	2. *Instructor Notebo* pages 10.3.1 - 10.3.5
	3. Analyze management problems	3. Problem solving	3. Frequent reference to *Trainee Notebook* materials	
			4. Trainee problem solving and reporting results	

Summary of Unit of Instruction 11: Activated Sludge

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Introduction to Activated Sludge Process Troubleshooting 60 minutes	1. Define activated sludge process objective	1. Objectives of the Unit of Instruction	1. Illustrated lecture with class discussion	1. *Trainee Notebook* page T11.1.1
	2. Identify controllable variables in activated sludge processes	2. Activated sludge process objective and the concept of sludge quality		2. *Instructor Notebook*, pages 11.1.1 - 11.1.44
	3. Identify factors which affect activated sludge process performance	3. The operator's goals and functions in process control		3. Slides 179.2/11.1.1 - 179.2/11.1.20
		4. Controllable variables which can be manipulated to achieve the activated sludge process objective		4. *Operational Control Procedures for the Activated Sludge Process*
		5. Factors which affect sludge quality and hence impact the achievement of the process objective		5. *Operator's Pocket Guide to Activated Sludge*
				6. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
2. Process Control Concepts for Activated Sludge	1. Define activated sludge process control parameters	1. Activated sludge process parameter formulas, limitations and uses	1. Illustrated lecture with classroom discussion	1. *Trainee Notebook*, pages T11.2.1 - T11.2.8
50 minutes	2. Identify uses and limitations of process control parameters	2. Effect of solids storage in the final clarifier on process control management		2. *Instructor Notebook*, pages 11.2.1 - 11.2.40
	3. Define final clarifier process control strategies	3. Use of trend data in process control		3. Slides 179.2/11.2.1 - 179.2/11.2.15
	4. Identify significance of trend charts in process control			4. *Operational Control Procedures for the Activated Sludge Process*
				5. *Operator's Pocket Guide to Activated Sludge*
				6. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
3. Activated Sludge Process Variations 25 minutes	1. Identify activated sludge process variations	1. Performance characteristics of activated sludge process variations	1. Illustrated lecture with class discussion	1. *Trainee Notebook*, pages T11.3.1
	2. Identify performance characteristics of activated sludge process variations	2. Application of mode change to activated sludge process troubleshooting		2. *Instructor Notebook*, pages 11.3.1 - 11.3.9
	3. Discuss application of mode change to activated sludge process troubleshooting			3. Slides 179.2/11.3.1 - 179.2/11.3.6
				4. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 56-57
4. Microscopic Evaluation of Sludge 25 minutes	1. Relate microscopic observations to sludge quality	1. Activated sludge microorganisms and their relationship to sludge quality	1. Illustrated lecture with class discussion	1. *Trainee Notebook*, pages T11.4.1 - T11.4.2
	2. Describe procedures for microscopic evaluation of activated sludge	2. Procedures for using the microscope to examine activated sludge		2. *Instructor Notebook*, pages 11.4.1 - 11.4.22

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
4. Continued				3. Slides 179.2/11.4.1 - 179.2/11.4.22
				4. *Operator's Pocket Guide to Activated Sludge, Part I: The Basics*, pages 7 - 9
5. Process Control Based on Sludge Settleability 50 minutes	1. Describe laboratory procedures for measuring sludge settleability	1. Laboratory procedures and calculations to measure sludge settleability	1. Illustrated lecture with class discussion	1. *Trainee Notebook*, pages T11.5.1 - T11.5.8
	2. Describe relationship of settling characteristics to sludge quality	2. Procedures to use settling data in process control decision making		2. *Operational Control Procedures for the Activated Sludge Process, Parts I and 2*
	3. Describe how sludge settling characteristics are interpreted for process control	3. Factors which affect sludge settleability		3. *Instructor Notebook*, pages 11.5.1 - 11.5.27
	4. Describe how process operating parameters affect sludge settleability	4. Relationship of sludge settleability to MCRT, F/M and RR		4. Slides 179.2/11.5.1 - 179.2/11.5.29
	5. Relate process control parameter observations to settling characteristics			

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
6. Respiration Rate Control Procedures 60 minutes	1. Define RR	1. Laboratory procedures and calculations to determine respiration rate	1. Illustrated lecture with class discussion	1. *Trainee Notebook*, pages T11.6.1 - T11.6.9
	2. Describe RR test procedures	2. Factors which affect respiration rate		2. *Instructor Notebook*, pages 11.6.1 -11.6.27
	3. Explain the significance of RR measurements in process control	3. Interpretation of respiration rate data for process control		3. Slides 179.2/11.6.1 - 179.2/11.6.49
	4. Relate RR measurements to F/M, MCRT, and sludge settleability observations	4. Relationship of process respiration rates to MCRT, F/M and sludge settleability		
	5. Describe the effect of process control changes on respiration rate observations			
7. Identifying Problem Causes in Activated Sludge 90 minutes	1. Interpret process control parameter observations to identify problems, their causes and corrective actions	1. Alternative causes for observed change in a given process control parameter	1. Trainee problem solving	1. *Trainee Notebook*, pages T11.7.1 - T11.7.11

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
7. Continued	2. Discuss and justify findings	2. Additional data needed to confirm most likely cause of an observed change in a given process control parameter	2. Trainee reports of findings	2. *Instructor Notebook*, pages 11.7.1 - 11.7.9
	3. Define interrelationships between process control parameter observations	3. Corrective actions to respond to possible causes of process control problem in activated sludge	3. Discussion of findings	3. *Instructor Notebook*, pages H11.7.1 - H11.7.27 (Handout to be reproduced prior to the class session)
			4. Distribution of solution sheets	
8. Visual Observations in Troubleshooting 60 minutes	1. Apply the Process of Troubleshooting to activated sludge process	1. The Process of Troubleshooting	1. Illustrated lecture	1. *Operational Control Procedures for the Activated Sludge Process, Part I*
	2. Describe visual observations to be made and their significance in troubleshooting	2. Visual observations in activated sludge plants and their significance in process control and troubleshooting	2. Trainee problem solving and discussion	2. *Instructor Notebook*, pages 11.8.1 - 11.8.25
	3. Demonstrate an ability to interpret visual observations			3. Slides 179.2/11.8.1 - 179.2/11.8.67

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
9. Case History: Pullman Treatment Plant 50 minutes	1. Apply the process of troubleshooting to a case history problem	1. Pullman Treatment Plant background information and problem statement	1. Trainee problem solving	1. *Trainee Notebook*, pages T11.9.1 - T11.9.8
			2. Instructor answers trainee questions by role playing the operator	2. *Instructor Notebook*, pages 11.9.1 - 11.9.6
10. Case History: Pullman Treatment 50 minutes	1. Report findings of lesson 9 problem solving exercise	1. Trainee solutions to the Pullman Case History	1. Trainee's report findings	1. *Trainee Notebook*, pages T11.9.1 - T11.9.8
	2. Present solution actually implemented at Pullman	2. Solution implemented at Pullman	2. Instructor leads discussion	2. *Instructor Notebook*, pages 11.10.1 11.10.6
	3. Demonstrate application of respiration rate control procedures		3. Instructor presents actual solution using illustrated lecture technique	3. Slides 179.2/11.101 - 179.2/11.10.8
			4. Instructor distributes solution to Pullman problem	4. *Instructor Notebook*, pages H11.101 - H11.10.11 (Handout to be reproduced prior to class session)

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
11. Hamsborough Case History 60 minutes	1. Apply the process of troubleshooting to an activated sludge plant problem	1. Hamsborough Treat Plant problem statement	1. Trainee problem solving	1. *Trainee Notebook*, pages T11.11.1 - T11.11.6
	2. Report findings of of problem solving	2. Trainee findings for Hamsborough problem	2. Trainees report and discuss their findings	2. *Instructor Notebook*, pages 11.11.1 - 11.11.7
		3. Solution implemented at Hamsborough	3. Instructor presents the solution implemented at Hamsborough	3. Slides 179.2/11.11.1 - 179.2/11.11.23
12. Sludge Settling Problems 120 minutes	1. Identify four types of sludge settling problems	1. Bulking definition	1. Illustrated lecture with class discussion	1. *Trainee Notebook*, pages T11.12.1 - T11.12.16
	2. Define bulking	2. Types of sludge settling problems		2. *Instructor Notebook*, pages 11.12.1 - 11.12.47
	3. Identify the causes of sludge settling problems	3. Causes of sludge settling problems		3. Slides 179.2/11.12.1 - 179.2/11.12.54
	4. Recommend corrective actions for different sludge settling problems	4. Corrective actions for sludge settling problems		
	5. Estimate final clarifier solids handling capacity	5. Procedures to estimate final clarifier solids handling capacity		

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
13. Mini-Case Histories 50 minutes	1. Apply the process of troubleshooting to the following problems a. Hydraulic surging b. Flow imbalance c. Short circuiting d. Return sludge control at small plants e. Inadequate mixing f. Final clarifier flow imbalance	1. Verbal and visual descriptions of problem statements and solutions	1. Instructor presents problem 2. Trainees solve problem 3. Trainees report findings 4. Class discusses problems and findings	1. *Instructor Notebook*, pages 11.13.1 - 11.13.11 2. Slides 179.2/11.13.1 - 179.2/11.13.28
14. Unit Summary 50 minutes	1. Summarize Unit of Instruction 2. Answer questions from class	1. Principal points covered in Unit of Instruction 11, Activated Sludge 2. Respond to questions asked by trainees	1. Illustrated lecture 2. Question and answer period	1. *Trainee Notebook*, pages T11.14.1 - T11.14.3 2. *Instructor Notebook*, pages 11.14.1 - 11.14.21 3. Slides 179.2/11.14.1 - 179.2/11.14.7

Summary of Unit of Instruction 12: Solids Handling

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Anaerobic Digestion 60 minutes	1. Describe anaerobic digestion in understandable terms	1. Importance of solids handling and solids handling problems	1. Instructor to follow lesson outline	1. *Trainee Notebook*, pages T12.1.1 - T12.1.4
	2. Identify and sketch various types of digesters	2. Communication problems between engineers and operators	2. Use of slide series and slide key	2. *Instructor Notebook*, pages 12.1.1 - 12.1.18
	3. Identify anaerobic digestion process parameters to measure	3. Significant process parameters in anaerbic digestion	3. Stimulation of trainee discussion by instructor	3. Slides 179.2/12.1.1 - 179.2/12.1.34
	4. List operating problems and approaches to investigating and correcting problems in anaerobic digestion	4. Troubleshooting anaerobic digestion problems		4. Process of Troubleshooting Chart, *Trainee Notebook*, page T2.2.8
				5. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*
2. Problem Solving in Anaerobic Digestion - "Fishbowl Technique	1. Employ the Process of Troubleshooting	1. Troubleshooting techniques	1. Role playing by trainee groups of troubleshooters	1. "Instructions to Troubleshooters: Problem 1," *Trainee Notebook*, page T12.2.1

Summary of Unit of Instruction 12: Solids Handling (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
110 minutes	2. Experience problems confronted by treatment plant operators	2. Relationships with operators	2. Observation of techniques by trainee reporters	2. "Instructions to Troubleshooters: Problem 2, *Trainee Notebook*, page T12.2.2
	3. Critique the trouble-shooting techniques of others	3. Troubleshooter behavior	3. Feedback on troubleshooting techniques given by trainee observers	3. *Instructor Notebook*, pages 12.2.1 - 12.2.11
	4. Have their trouble-shooting techniques critiqued	4. Feedback on using trouble-shooting techniques and trouble-shooting behavior	4. Class discussion of results and and experiences	4. "Instructions to Operators: Problem 1", *Instructor Notebook*, pages H12.2.1 - H12.2.2 (Reproduce for distribution)
				5. "Instructions to Operators: Problem 2, *Instructor Notebook*, pages H12.2. - H12.2.5 (Reproduce for distribution)
3. Other Methods of Solids Handling 90 minutes	1. List and identify six unit processes of solids handling	1. Understanding normal process	1. Use lesson outline, with word slides as focal point of class discussion	1. *Trainee Notebook*, pages T12.3.1 - T12.3.11

Summary of Unit of Instruction 12: Solids Handling (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
	2. Describe normal operations and evaluation tests for each process	2. Evaluating process operations	2. Picture slide series on aerobic digestion	2. *Instructor Notebook*, pages 12.3.1 - 12.3.32
	3. Identify operating problems, causes and corrective actions for each process	3. Troubleshooting common operational problems	3. Frequent use of *Trainee Notebook* materials	3. Slides 179.2/12.3.1 - 179.2/12.3.53
			4. Delete processes not found in area where course is given	4. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*
4. Tall Tales or "Where Did All That Sludge Come From?"	1. Identify actual solids handling problems and the approaches to solving them	1. Solids handling problems encountered in the region where the course is presented	1. Trainees provide actual problems, instructor screens and selects problems for discussion	1. *Instructor Notebook*, pages 12.4.1 - 12.4.3
40 minutes	2. Recommend alternative approaches to solving problems		2. Selected problems are discussed by class	

Summary of Unit of Instruction 12: Solids Handling (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
5. Applying the Process of Troubleshooting 40 minutes	1. Analyze and troubleshoot a vacuum filtration problem	1. Case study-actual problem of plant failure due to improper solids handling	1. Instructor presents case study problem as the "operator"	1. Process of Troubleshooting Chart, *Trainee Notebook*, page T2.2.8
	2. Discuss the connection between solids handling and overall treatment plant performance		2. Trainees "troubleshoot" the problem, advise on its solution	2. *Instructor Notebook*, pages 12.5.1 - 12.5.7

Summary of Unit of Instruction 13: Land Treatment

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
1. Land Treatment Systems 75 minutes	1. Identify elements of land treatment systems	1. Similarity of effluent and sludge application	1. Instructor to follow lesson outline	1. Slides 179.2/13.1.1 - 179.2/13.1.40
	2. Describe prior treatment requirements	2. Need for effective prior treatment	2. Use of word and picture slides and key	2. *Trainee Notebook*, page T13.1.1, "Application Rate of Wastewater"
	3. List the factors in transporting effluents and sludges	3. Importance of uniform distribution	3. Stimulate trainee discussion	3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 242-255 and 392-397
	4. Identify distribution systems	4. Monitoring of sludge prior to application	4. Importance of trainee questions	4. *Instructor Notebook*, pages 13.1.1 - 13.1.24
	5. Describe soil, crop and outflow considerations in land treatment	5. Need for monitoring outflow		
2. Troubleshooting Operational Problems 45 minutes	1. Recognize common land treatment problems	1. Four operational problems for trainee groups to identify causes	1. Trainees work in groups	1. Slides 179.2/13.2.1 - 179.2/13.2.12
	2. Determine alternative causes of problems	2. Causes of the following problems:	2. Instructor presents problem	2. *Instructor Notebook*, page 13.2.1 - 13.2.9

Summary of Unit of Instruction 13: Land Treatment (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
		a. Pooling of water b. Poor corn growth c. Broken pipes d. Soil erosion	with a brief description and slides	
	3. Evaluate responses to land application problems		3. Group has 5 minutes to idenfy the causes to each problem	3. "Troubleshooting Guide on Land Treatment", *Trainee Notebook* pages T13.2.1 - T13.2.8
	4. Identify specific causes to land treatment problems		4. Trainees present their answers to problems	4. *Trainee Notebook*, pages T13.2.9 - T13.2.10, "References
			5. Instructor stimulates class discussion	

Summary of Unit of Instruction 14: Disinfection

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Chlorination 30 minutes	1. Define purposes of chlorination in wastewater treatment	1. Purposes of chlorination	1. Illustrated lecture	1. *Instructor Notebook*, pages 14.1.1-14.1.14
	2. Identifying types of chlorination systems	2. Types of chlorination systems	2. Frequent trainee reference to *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*	2. Slides 179.2/14.1.1-179.2/14.1.18
	3. Identify common problems in chlorination system operations	3. Common operational problems		3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pp. 129-141
2. Ozonation	1. Define purposes of ozonation	1. Purposes of ozonation	1. Illustrated lecture	1. *Instructor Notebook*, pages 14.2.1-14.2.8
	2. Describe ozonation system	2. Ozonation system	2. Frequent trainee reference to *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*	2. Slides 179.2/14.2.1-179.2/14.2.8
	3. Identify common problems in ozonation system operations	3. Common problems in ozonation		3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*
				4. *Trainee Notebook*, page T14.2.1

Summary of Unit of Instruction 15: Closing

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Course Summary 30 minutes	1. Summarize the Process of Troubleshooting and its application to problem solving in wastewater treatment facilities	1. The process of troubleshooting	1. Illustrated lecture	1. *Instructor Notebook*, pages 15.1.1-15.1.6
	2. Award Certificates	2. Characteristics of a successful troubleshooting project	2. Certificate Awards	2. Certificates of Completion for each trainee (to be provided by the Course Director)
2. Trainee Post-Course Assessment	1. Demonstrate achievement of course objectives	1. Written examination covering course content	1. Written examination	1. Trainee Post-Course Examination (to be prepared by Course Director from the listing of questions provided in the *Instructor Notebook*) 2. Answer sheets (to be prepared by the Course Director) 3. Grading Key (to be prepared by the Course Director)

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

GUIDELINES FOR THE COURSE DIRECTOR

APPENDIX D

Checklist of Activities for Presenting the Course

A. Pre-Course Responsibilities

____ 1. Reserve and confirm classroom(s), including size, "set-up", location and costs (if any).

____ 2. Contact and confirm all faculty (speakers) for the course(s), including their A-V requirements. Send material to them.

____ 3. Reserve hotel accommodations for faculty.

____ 4. Arrange for and confirm food service needs (i.e., meals, coffee breaks, water, etc.).

____ 5. Review and modify program curricula for local differences based on your assessment of needs.

____ 6. Prepare and reproduce final ("revised" if appropriate) copy of the detailed program schedule.

____ 7. Reproduce final registration/attendance roster, including observers (if any).

____ 8. Prepare and send letter(s) of confirmation and instruction to all trainee participants (include biographical and educational questionnaire/information sheet to be returned by each participant - if used).

____ 9. Prepare and sign "Certificates of Completion" (if used).

____ 10. Prepare name badges and name "tents" for trainees and faculty.

____ 11. Identify, order and confirm all A-V equipment needs.

____ 12. Prepare two or three 12 in. x 15 in. signs on posterboard for posting at meeting area.

____ 13. Arrange for and confirm any special administrative assistance needs on-site for course, including "local" Address of Welcome, etc.

____ 14. Obtain copies of EPA Manuals and Activated Sludge Pamphlets (See Appendix B).

____ 15. Reproduce *Trainee Notebook* (See Appendix B).

____ 16. Reproduce trainee materials to be handed out by the instructors (See Appendix B).

____ 17. Pack and ship box of supplies and materials one week prior to beginning of course (if appropriate).

B. On-Site Course Responsibilities

____ 1. Check on and determine final room arrangements (i.e., tables, chairs, lectern, water, cups, etc.).

____ 2. Set up A-V equipment required each day and brief operator (if supplied).

____ 3. Post signs where needed.

____ 4. Alert receptionist, phone operator(s), watchmen, etc. of name, location and schedule of program.

____ 5. Set up and handle final registration check-in procedures (including instruction to auxiliary help at registration desk).

____ 6. Conduct a new speaker(s) (i.e., instructor) briefing session on a daily basis.

____ 7. Verify and make final food services/coffee arrangements (where appropriate).

____ 8. Identify and arrange for other physical needs as required (i.e., coat racks, ashtrays, etc.).

____ 9. Make a final check on arrival of guest speakers (instructors) for the day.

____ 10. Award certificates on last day of course.

C. Post-Course Responsibilities

____ 1. Request honorarium and expense statements from faculty, order and process checks.

____ 2. Write thank-you letters and send checks to paid faculty.

____ 3. Write thank-you letters to non-paid guest speakers.

____ 4. Prepare evaluation on each course (including instructions, content, facilities, etc.).

____ 5. Make sure A-V equipment is returned.

____ 6. Return unused materials to your office.

____ 7. Relax, have a beer and pat yourself on the back for a job well done!

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 1: Overview

Unit 1 of 15 Units of Instruction

Lessons in Unit: 4 Recommended Time: 3 hours

Instructor Overview of the Unit

Rationale for Unit: The *Overview* unit sets the tone and direction for the course, provides the trainee an introduction to the course content, establishes the importance of technical assistance in meeting water quality goals, introduces the trainee materials, assesses trainee knowledge on entering the course and establishes communication between work group members. In addition the *Overview* provides an opportunity for the Course Director to orient trainees to the course format, schedule and logistics.

The *Overview* unit should be used in all presentations of the *Troubleshooting O & M Problems in Wastewater Treatment Facilities* training materials.

Trainee Entry Level Behavior: As a prerequisite to the course the trainee should be able to:

1. Given a photograph, drawing, schematic or verbal description of wastewater treatment equipment or processes, the trainee will be able to:
    a. Identify and name the treatment equipment or process unit;
    b. State the purpose and function of each piece of equipment and each unit in the process;
    c. Identify, point out and name the component parts of the equipment or process;
    d. Describe how each component works and why it is important to the performance of the overall treatment system;
    e. List the typical operating ranges of control parameters

for equipment, unit processes and their component parts; and

f. Describe the normal or routine operation and maintenance procedures for equipment, unit processes and their component parts.

2. Given essential design and operating data for equipment, unit processes or treatment systems:

   a. State whether or not the equipment, unit process or treatment system is performing normally; and

   b. State whether or not the equipment, unit process or treatment system is performing satisfactorily.

3. Given access to wastewater treatment equipment, unit processes and systems which are operating well, perform normal or routine process control, operations and maintenance tasks correctly.

Trainee Learning Objectives: Upon completion of the *Overview* Unit of Instruction, the trainee will be able to do the following:

1. When meeting course faculty, staff and fellow trainees, the trainee will be able to recognize the individual, state the individual's name, describe his/her role in the course and state pertinent facts about the individual's background;

2. From memory the trainee will be able to list the course objectives;

3. Given access to the *Trainee Notebook* materials, the trainee will be able to locate the course agenda, describe how the course will be presented and state the trainee's responsibilities in the course;

4. When in the course meeting facilities, the trainee will be able to identify and locate all rooms, such as the main lecture room, break-out rooms, restrooms, eating facilities, etc., to be used in the course or by the trainees.

5. Demonstrate his/her knowledge of wastewater treatment operations by completing the Trainee Assessment (Unit 1, Lesson 2).

6. From memory, the trainee will be able to explain the significance of O & M in attaining water quality goals, list program options available to local, state and federal agencies to achieve compliance with point-source discharge objectives, and discuss the advantages and disadvantages of each option;

7. The trainee will be able to state his/her work group number and identify the members of his/her work group;

8. When presented a problem statement while playing the Board Game (Unit 1, Lesson 4), the trainee will be able to discuss the problem and solution options with members of his/her work group and reach a concensus opinion as to the preferred solution to the problem.

Sequencing and Pre-Course Preparation for the Unit: Unit 1 *Overview* is presented as four lessons:

Lesson 1. Welcome, Introduction and Orientation

Recommended Time: 30 minutes

Purpose: Welcomes trainees to course, provides opportunity to introduce faculty and trainees, and orients trainees to course materials and setting.

Training Facilities:

a. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees in groups of four;

b. Instructor table with lectern;

c. Large projection screen (6' x 6' minimum) and chalkboard in front of room and readily visible to all trainees;

d. Easel with pad;

e. 35mm carousel projector with remote control changer at instructor table;

f. At least four empty carousel trays;

g. Overhead projector;

h. Chalk, felt-tip markers and erasers;

i. Six to eight chairs randomly spaced at back and sides of room for visitors.

Pre-course Preparation:

1. Reproduce or purchase and locate at each trainee seating position the following:

   a. *Trainee Notebook* (see *Guidelines for the Course Director*, Appendix A and B for detailed listing of materials to be included in the *Trainee Notebook*).

   b. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA-430/9-78-001, Municipal Operations Branch, Office of Water Program Operation, U.S. Environmental Protection Agency, Washington, D.C. 20460 (January, 1978).

   c. *Operators Pocket Guide to Activated Sludge, Part I: The Basics* and *Part II: Process Control and Troubleshooting*, STRAAM Engineers, Inc., 5505 S.E. Milwaukie, Portland, Oregon 97202 (1975).

   d. West, A.W., *Operational Control Procedures for the Activated Sludge Process*, Parts I, II, IIIA, IIIB, and Appendix, National Training and Operational Technology Center, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

   e. West, A.W., "Updated Summary of the Operational Control Procedures for the Activated Sludge Process," National Training and Operational Technology Center, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268 (January, 1978).

   f. West, A.W., "Dynamic Sludge Age," National Training and Operational Technology Center, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268 (1979).

   g. List of trainees pre-registered for course sorted by work group with names, job titles, employer addresses and telephone numbers.

h. A name tag for each trainee.

i. Table name plate for each trainee (last name only).

2. Table sign designating work group number should be located at each 4-member work group seating position.

3. Table name plates and name tags should be prepared for each instructor. The appropriate table name plate should be placed on the instructor's table as instructors are teaching.

4. Reproduce and store in a convenient location all hand-outs to be used by instructors in the several units of instruction. A complete listing of hand-outs required for the course is found in *Guidelines for the Course Director*, Appendix B.

5. It is suggested that the Course Director have available a back-up set of all instructor materials (see *Guidelines for the Course Director*, Appendix A) in the event that an instructor loses, forgets or otherwise misplaces his/her materials.

Instructional Approach: Lecture with trainee participation.

Lesson 2. Trainee Assessment

Recommended Time: 30 minutes

Purpose: Assess trainee knowledge of wastewater treatment operations to identify strengths and weaknesses of class and individual trainees.

Training Facilities: Same as Lesson 1, Unit 1.

Pre-Course Preparation: Reproduce and have available for distribution copies of the Trainee Assessment and answer sheets.

Instructional Approach: Written examination

Lesson 3. The Significance of Plant O & M

Recommended Time: 30 minutes

Purpose: Identifies factors which affect the performance of wastewater treatment facilities, explains how in-plant technical assistance or troubleshooting may be used to improve plant performance and relates technical assistance to federal and state water pollution control programs.

Training Facilities: Same as Lesson 1, Unit 1.

Pre-Course Preparation: No special preparation for this Lesson is required.

Instructional Approach: Lecture with trainee discussion

Lesson 4. Evaluating Treatment Plant Operations: A Board Game

Recommended Time: 90 minutes

Purpose: Introduces typical performance problems at wastewater treatment facilities, establishes student work groups, breaks down communication inhibitions in work group and establishes trainee and faculty interaction and discussion as principal teaching tool in the course.

Training Facilities: A separate room adjacent to or conveniently located to main training room set up with card tables with seating for four at each table. One table for each work group of four trainees is needed. Room set-up is typical hotel set-up for a "card-party."

Pre-Course Preparation:

1. One complete set of Board Game materials at each table (see *Guidelines for the Course Director*, Appendix A and B).
2. Gag prizes for winning and losing groups.

Instructional Approach: Simulation by trainee game playing followed by informal discussion and feedback.

Presentation Options for the Course Director: The 180 minute unit *Overview* is an essential introduction to this course. The developers of the course believe that this lesson must be used if the course is to be successful in its objectives. Accordingly, the options for varying from the instructional plan for this unit are limited. Some possible alternative methods of presentation are suggested below should they be considered appropriate by the Course Director.

Lesson 1. Welcome, Introduction and Orientation. Little variation in this subdivision is possible. Because one of the objectives is to establish a comfortable and informal environment, it may be possible to present this lesson outside of the classroom, such as in a lounge. In one location, where the course began after lunch on the first day, this subdivision was presented in the dining room where all of the students and faculty were lunching together.

Lesson 2. Trainee Assessment. Little variation is possible. The trainee assessment is necessary to guide the Course Director and instructors.

Lesson 3. The Significance of Plant O & M. This subdivision offers considerable possibility for variation. Organizations presenting this course may substitute discussions of their own policies and programs for the prepared materials as long as the overall lesson objectives are met. It would also be possible to expand this subdivision beyond 30 minutes to provide additional discussion on organizational or regulatory agency policies. However, experience with this material shows that many course participants get very impatient with this type of lesson.

The orientation of this lesson must be modified to fit the class. The roles of plant operators, private sector technical assistance personnel and regulatory agency personnel in troubleshooting are quite different. The base lesson plans are structured for a class composed primarily of private sector consultants.

Lesson 4. Evaluating Treatment Plant Operations: A Board Game. Little variation is possible in the presentation of the board game. However, because each of the trainee groups play the game using only one-half of all the problems, it would be possible to repeat the game later in the course with each group given the remaining set of problems. However, the developers of the course believe that there would be little educational purpose served by a repetition of the game.

SUMMARY OF UNIT OF INSTRUCTION 1: *OVERVIEW*

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS & CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Welcome, Introduction & Orientation 30 minutes	1. Familiarize trainees with purpose and nature of course.	1. Introduction of students and faculty.	1. Follow lesson outline. 2. Be informed. 3. Make trainees feel comfortable.	1. *Trainee Notebook* (see *Guidelines for the Course Director*, Appendix A and B). 2. *Field Manual for Perforamnce Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*
2. Trainee Assessment 30 minutes	1. Assess trainee knowledge of treatment plant operations.	1. Exam on various facets of treatment plant operations.	1. Instructor supervises exam. 2. Instructor present to answer questions.	1. Trainee assessment exam. 2. Answer sheet 3. Answer key
3. The Significance of Plant O & M 30 minutes	1. Relate technical assistance and troubleshooting O & M problems to attainment of water pollution control program goals.	1. Importance of a balanced regulatory/assistance approach to controlling municipal discharges.	1. Follow lesson plan outline, using slides and key. 2. Trainee discussion at appropriate points	1. Lesson plan with selected slides 2. *Trainee Notebook*,

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS & CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
	2. Identify factors which affect the performance of treatment plants.	2. Magnitude & scope of O & M problem. 3. Survey results which document factors affecting plant performance.	3. Reference to *Trainee Notebook*	
4. Evaluating Treatment Plant Operations: A Board Game. 90 minutes	1. Breakdown trainee work group communication inhibitions. 2. Orient trainees to typical O & M problems in treatment plants. 3. Involve trainees in problem solving.	1. Broad overview of course. 2. Working relationship between members of trainee groups. 3. Treatment plant problem solving 4. Troubleshooting as a process to solve complex problems.	Instructor supervises four stages to game. 1. Preparation 2. Instructions and initiation of play. 3. Play 4. Conclusion of play	Complete sets of game materials for each trainee work group.

Unit of Instruction 1: Overview

Lesson 1: Welcome, Introduction and Orientation

Lesson 1 of 4 lessons Recommended Time: 30 minutes

Purpose: The lesson provides an opportunity to welcome trainees to the course, define the course objectives, orient the trainees to course approach, agenda and training facilities and introduce trainees and faculty.

Trainee Entry Level Behavior: As specified in the Instructor Overview of the Unit, page 1.1.

Trainee Learning Objectives: At the conclusion of this lesson the trainee will be able to:

1. Recognize faculty and other trainees by name, occupation and job duties;
2. List the course objectives;
3. Recognize the *Trainee Notebook* and other trainee resource material and locate appropriate sections in the trainee materials when asked to do so;
4. Describe the trainee's role in the course as an active learner who will participate in various group learning activities and his/her responsibility to be present as required by the course agenda;
5. Describe how the course will develop in accordance with the course agenda;
6. State his/her work group number and identify the other members of his/her work group;
7. Locate essental features of the training facility such as classrooms, restrooms, break-out areas, restaurants, etc.

Instructional Approach: Lecture with a question and answer period.

The instructor should be informal and attempt to establish a relaxed atmosphere which will encourage trainee participation in the course and set an ambiance for open two-way communication between trainee and instructional staff.

It is recommended that the instructor follow the outline provided in the lesson plans.

Lesson Schedule: Within the 30 minutes allocated to Lesson 1, the following schedule should be observed in presenting the lesson plan:

TIME	SUBJECT
0 - 5 minutes	Welcome and Introduction
5 - 25 minutes	Introduction to the Course
25 - 30 minutes	Official Welcome

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, Section 1.1

2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 1, Lesson 1, pages 1.1.1 - 1.1.7

2. No slides or other visual aids are used in this lesson

Instructor Materials Recommended for Development: None

Additional Instructor References: None

Classroom Set-Up: Large classroom (40'x40') with table and chair seating set in "herring bone" or "U" shape will all seats facing the front of the room. Trainees should be seated in groups of four in pre-assigned work groups. Individual work groups should be seated at the table whose number corresponds to the work group number. Trainee materials should be placed on the tables in front of trainee seats. Trainee name plates should be placed on the table so they are visible from the instructor's table. An instructor's table with lectern snould be located at the top of the "herring bone."

Although not used in this lesson, the room should be equipped with a large projection screen (6'x6' minimum), a chalkboard, an easel, a 35mm carousel projector with remote control at the instructor's table, four empty carousel trays and an overhead projector. All supplies such as chalk, erasers, marking pens, etc., should be available.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Welcome and Introduction of Trainees (5 minutes)	
A. Give brief words of welcome (1 min.)	
B. Introduction of trainees (4 min.) Each trainee should stand up and introduce themself by giving: 1. His/her name 2. Where he/she works and for whom 3. The nature of his/her work	
C. Tell trainees that this course is designed so that trainees learn from each other. Therefore *they* are important to this course and should be introduced first.	
II. Introduction to the Course (20 min.)	
A. Introduction of Faculty (2 min.) Introduce all faculty, staff, special guests and other persons associated with the course.	
B. Course Materials (2 min.) Introduce the students to the primary materials used for the course.	Guide: Instructor should show each of the primary course materials to the class as he discusses them.
1. *Trainee Notebook* - complete with reference materials, references and worksheets to be used by trainees as they are taking the course. This notebook should be present during all course lessons.	
2. EPA Manual - *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*	Guide: This manual is a major reference on plant troubleshooting. It should be used with the course and distributed to students whenever it is available.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. Other Course Materials If other course materials are to be used, they should be introduced at this point.	
C. Acknowledgements (1 min.)	
1. Refer trainees to page T1.1.1, *Trainee Notebook*, Acknowledgements	
D. Course Objectives (5 min.)	
1. Refer trainees to Statement of Objectives, *Trainee Notebook*, page T1.1.3	
2. Read objectives out loud to class and discuss each briefly	
3. Ask for questions and comments	
4. It is important that the trainees appreciate the objectives of this course from the outset. It is important for them to understand their expected behavior and capability at the completion of the course.	
E. Course Format and Schedule (5 min.)	Note to Course Director: Course agenda and index of notebook subjects should be numbered sequentially beginning with page number T1.1.5. The total number of pages will depend on the detail included in the agenda.
1. Refer trainees to the *Trainee Notebook* pages which include the agenda and the index of subjects covered and briefly review the course agenda.	
2. Discuss the following points.	
a. The course is structured into separate topics reflecting different treatment plant operations. This structure	Key Point: Importance of viewing treatment plants as a *system* using a *systematic* approach to troubleshooting.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
is done primarily to facilitate the presentation of course materials and the assignment of instructors. However, treatment plants are considered as *waste treatment systems* and troubleshooting should utilize a "system approach."	The system approach will be used in developing the course materials.
b. The course stresses *problem solving*.	
c. The course emphasizes *trainee participation* and involvement. The trainees will learn from each other as well as from the instructors. Experienced trainees have much to contribute to this course. Tell trainees that they should not hesitate to join in whenever they have something to contribute or a question which needs clarifying.	
d. The course utilizes a variety of instructional techniques to keep their interest. It has been shown that different people seem to respond best to different types of approaches. Alert trainees to their group assignments and stress that they are a team working together.	
e. Briefly discuss who the instructors will be and their backgrounds.	Note to Course Director: Supplement the lesson plan with brief biographical sketches of instructional staff.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
f. Call attention to the course schedule and the specifics of the schedule as appropriate to the particular presentation including: Course hours and days, including starting times, coffee breaks, lunch breaks and closing times. Any evening sessions or other schedule deviations. Any take-home efforts or out-of-class efforts required of the trainees.	
g. Stress that the instructors will adhere to the schedule as closely as possible. Emphasize the trainee responsibility to be punctual and present. Reassert the role of the trainee as an active participant as both learner and teacher in the course.	
III. Orient Trainee to Training Facilities Identifying Key Rooms and Their Locations	Note to Course Director: A floor plan of the facility would be a useful training aid.
IV. Official Welcome (5 minutes) If possible, trainees should be given a brief welcome from a senior official of the organization sponsoring the course. The official should note: A. The importance of plant O & M to achieving water-quality program objectives. B. The importance of troubleshooting	Note to the Course Director: A briefing paper describing the course, the trainees and the training objectives of the course as they relate to the program objectives of the sponsoring organization should be prepared and given to the welcoming official as a guide to him/her in preparing comments. Failure of the welcoming official to support the course objectives

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
and technical assistance to improving plant O & M.	and the trainees continued involvement in technical assistance and troubleshooting would be disasterous and largely negate any long-term benefit from the course.
C. The importance of cooperation between Federal, state and local governments, the private sector and facility owners and operators in achieving good plant performance.	
D. The role this course can play in improving the items listed in A-C above.	

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 1: Overview

Lesson 1: Welcome, Introduction and Orientation

Trainee Notebook Contents

Acknowledgements T1.1.1

Course Objectives T1.1.3

Course Agenda T1.1.5

List of Attendees T1.1.7

Acknowledgements

The training course and materials were developed by the Environmental Resources Training Center, Southern Illinois University at Edwardsville under Training Grant No. T900783-01-0. The following persons contributed significantly to the course development and content:

Environmental Resources Training Center
Southern Illinois University
Edwardsville, IL 62026

James O. Bryant, Jr., Director
Susan A. Castle, Program Director
John L. Krantz, Coordinator

Participating Consultants:

Terry M. Regan, T.M. Regan, Inc., Lexington, KY
Charles S. Zickefoose, STRAAM Engineers, Inc., Portland, OR
William R. Hill, Floyd G. Browne and Associates, Ltd., Marion, OH
Paul G. Klopping, Linn-Benton Community College, Albany, OR

National Training and Operational Technology Center
Environmental Protection Agency
Cincinnati, OH

James Walasek, Project Officer
Thomas Schwing
Lynn Marshall
Audrey Kroner

The course was based on a course originally developed by the American Public Works Association for the EPA under Training Grant No. T900535-01-0. The following persons contributed significantly to the original course development:

American Public Works Association

Richard H. Sullivan
Malcolm C. Van Dursen
Ira L. Whitman, Project Director

Participating Consultants

Andrew P. Pajak, Green Engineers International,
Sewickley, PA
Bobby D. Whitefield, Dudley E. Farr, Herbert T. Neuman,
Texas Water Quality Board, Austin, TX
Terry M. Regan, T.M. Regan, Inc., Lexington, KY
Earl A. Myers, Williams & Works Engineers, Grand Rapids, MI
Robert Manson, Charles Hull, Cliff Merritt, Ray Saneholtz,
Greg Binder, Ohio EPA, Bowling Green, OH
Robert C. Polta, Richard W. DeFore, Metropolitan Waste
Control Commission, St. Paul, MN
David L. Sullivan, Engineering-Science, Inc., Berkeley, CA
Ronald F. Layton, Water and Wastewater Technical School,
Neosho, MO
James C. Haube, Water Pollution Control Department,
Perrysburg, OH
Charles S. Zickefoose and R. B. Hayes, STRAAM Engineers,
Inc., Portland, OR
Donald Goldenbaum, Kansas City, MO

EPA Technical Review Committee:

James O. Bryant, Jr., Environmental Resources Training Center,
Southern Illinois University, Edwardsville, IL
John W. Meagher, Municipal Operations Branch, EPA,
Washington, D.C.
F. J. Ludzack, National Training and Operational Technology
Center, Cincinnati, OH
Joseph Joslin, EPA Region VII, Kansas City, MO
Art Gurley, EPA Region IV, Atlanta, GA
J. Edward Meers, Sanitary District of Bloom Township,
Chicago Heights, IL

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

COURSE OBJECTIVES

At the conclusion of the course you should be able to:

- List in sequence the steps in the *Process of Troubleshooting* and describe how the *Process of Troubleshooting* is applied when providing performance evaluation and technical assistance services to a wastewater treatment facility.
- Apply the *Process of Troubleshooting* to evaluate and improve the performance of a treatment facility. Specifically, you should be able to:
    - Establish effective communication with plant management, plant operating personnel and local, state, and Federal regulatory agency personnel.
    - Determine information and data needed to evaluate the system's performance, to identify problems and their causes, to list alternative solutions, to select and implement a preferred solution and to evaluate the effectiveness of the solution in improving plant performance.
    - Gather and analyze available data to identify the problems which are contributing to inadequate performance and to assign the causes among such factors as operation, maintenance, loading, process control procedures and strategy, design, management/administration and other functions.
    - Analyze data to determine the corrective programs or procedures most likely to be effective in particular situations and implement corrective actions to improve treatment plant operations and performance.
    - Monitor the short and long term effectiveness of the corrective actions implemented.
- Given the instructor and student training materials for the course *Troubleshooting O & M Problems in Wastewater Treatment Facilities*, organize and present the training course.

The course will assist you to accomplish these objectives by:

- Providing training in the *Process of Troubleshooting* and problem solving for operational problems at wastewater treatment facilities.

- Providing an overview of wastewater treatment plant operations and processes to serve as a *technical review* and supplement to upgrade the quality of *technical guidance* and *technical assistance* given to wastewater treatment plant owners, managers and operators.

- Exposing you to *realistic treatment plant operating problems*, their causes, effects and methods of correction.

- Applying the *Process of Troubleshooting* to the analysis and solution of case history problems based on actual operating experiences.

- Creating an awareness for the need for *cooperative relationships and attitudes* between all personnel involved in water pollution control facility operations and operations assistance.

- Providing an opportunity for you to practice and improve your *interpersonal communication skills*.

- Focusing your attention to the need to consider *management* (people related) *problems* as well as technical problems when evaluating treatment system operations.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Marcy, New York
April 28 - May 2, 1980

COURSE AGENDA

Monday, April 28

8:00 - 8:30 a.m.	Introduction and Overview	Bryant
8:30 - 9:00 a.m.	Significance of Plant O & M	Bryant
9:00 - 10:30 a.m.	Board Game - Evaluation Treatment Plant Problems	Bryant
10:30 - 11:30 a.m.	Elements of Troubleshooting	Bryant
11:30 - 12:30 p.m.	Lunch	
12:30 - 1:30 p.m.	Elements of Troubleshooting	Bryant
1:30 - 3:15 p.m.	Sewer Use Control	Hill
3:15 - 3:30 p.m.	Break	
3:30 - 5:00 p.m.	Pre/Primary Treatment	Hill

Tuesday, April 29

8:00 - Noon	Management Behavior	Hill
12:00 - 1:00 p.m.	Lunch	
1:00 - 2:00 p.m.	Introduction to Activated Sludge Process Troubleshooting	Bryant
2:00 - 3:00 p.m.	Process Control Concepts for Activated Sludge	Bryant
3:00 - 3:15 p.m.	Break	
3:15 - 3:45 p.m.	Activated Sludge Process Variations	Bryant
3:45 - 4:15 p.m.	Microscopic Evaluation of Activated Sludge	Bryant
4:15 - 5:15 p.m.	Process Control Based on Sludge Settleability	Bryant

Wednesday, April 30

8:00 - 9:00 a.m.	Respiration Rate Control Procedures	Zickefoose
9:00 - 11:00 a.m.	Identifying Common Problems in Activated Sludge Process Control	Bryant
11:00 - 12:00 p.m.	Visual Observations in Troubleshooting	Zickefoose

12:00 - 1:00 p.m.	Lunch	
1:00 - 3:00 p.m.	Final Clarifier Settling Problems	Zickefoose
3:00 - 3:15 p.m.	Break	
3:15 - 4:15 p.m.	Hamsborough Case History	Bryant
4:15 - 5:15 p.m.	Pullman Case History	Zickefoose

Thursday, May 1

8:00 - 9:00 a.m.	Pullman Case History	Zickefoose
9:00 - 10:00 a.m.	Activated Sludge Summary	Zickefoose
10:00 - 10:15 a.m.	Break	
10:15 - 12:00 p.m.	Fixed Media Biological Systems	Zickefoose
12:00 - 1:00 p.m.	Lunch	
1:00 - 5:00 p.m.	Solids Handling	Quick

Friday, May 2

8:00 - 10:00 a.m.	Solids Handling	Quick
10:00 - 10:15 a.m.	Break	
10:15 - 12:15 p.m.	Chemicals in Wastewater Treatment	Quick
12:15 - 1:15 p.m.	Lunch	
1:15 - 2:30 p.m.	Using the 179.2 Training Materials	Bryant
2:30 - 3:00 p.m.	Course Summary and Closing	Bryant

Unit of Instruction 1: Overview

Lesson 2: Trainee Assessment

Lesson 2 of 4 Recommended Time: 30 minutes

Purpose: This lesson tests the trainee's knowledge of wastewater treatment operations with specific reference to the knowledge of process control required to evaluate and troubleshoot wastewater treatment facilities. Interpretation of test results and their use in orienting the presentation to the trainees enrolled in the course are discussed in the lesson plan outline. The examination also serves to highlight the specific knowledge and skills which will be developed in the course.

The same examination is used as a post-test to aid the Course Director and trainee in evaluating individual and class achievement in the course.

Trainee Entry Level Behavior: Trainees will have completed Unit 1, Lesson 1.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be aware of the specific knowledge and skills about treatment plant evaluation and troubleshooting which will be developed in the course.

Instructional Approach: Trainees complete a multiple choice written examination. The instructor administers the examination, responds to trainee questions about the examination, grades the examinations and uses the results to counsel trainees in one-on-one sessions.

Lesson Schedule: Within the 30 minutes allocated to the lesson, the following schedule should be followed:

TIME	SUBJECT
0 - 3 minutes	Distribute Examination and Give Instructions
3 - 28 minutes	Trainees Complete Examination
28 - 30 minutes	Collect Completed Examinations

Trainee Materials Used in Lesson:

1. One copy of Trainee Assessment Answer Sheet for each trainee (*Instructor Notebook*, pages H1.2.1 - H1.2.2)
2. One copy of Trainee Assessment for each trainee (*Instructor Notebook*, pages H1.2.3 - H1.2.16)
3. Pencil or pen for each trainee

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 1, Lesson 2, pages 1.2.1 - 1.2.8.
2. No slides or other visual aids are used in this lesson

Instructor Materials Recommended for Development: Revise Trainee Assessment as appropriate to reflect any modifications in training materials used in specific course presentation.

Additional Instructor References: None

Classroom Set-Up: As specified in Unit 1, Lesson 1

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Distribute Trainee Assessment Materials (1 min.)	
A. Hand out Trainee Assessment Answer Sheets	Note to Course Director: Pages H1.2.1 -H1.2.2 of the *Instructor Notebook* should be reproduced as the Trainee Assessment Answer Sheet.
B. Hand out Trainee Assessment Questionnaire	Note to Course Director: Pages H1.2.3 -H1.2.16 of the *Instructor Notebook* should be reproduced as the Trainee Assessment Questionnaire
II. Give Oral Instructions to Trainees for Completing the Trainee Assessment (2 min.)	
A. Tell trainees that primary purpose of the Trainee Assessment is to provide information which can be used by course instructors to tailor their presentations to class needs. Although it is not used to evaluate individual students, each test will be graded and the results made available to the class and individual trainees	
B. Instruct trainees to enter their name and social security account number in the spaces provided on the Answer Sheet. Tell trainees that the SSAN will be used as a student identification number.	
C. Instruct trainees to circle the correct answer or answers on the Trainee Assessment Answer Sheet.	
D. Inform trainees that there may be more than one correct answer to each question. There are a total of 154 correct responses to the 75 questions. Inform them that three (3) scores will be calculated:	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
number of correct responses, number of incorrect responses and a net score which is the difference between the number correct and the number incorrect.	
E. Inform trainees that they must work quickly because they will have only 25 minutes to complete the Trainee Assessment.	
F. Remain in classroom to answer any trainee questions. Periodically inform class of time remaining.	
III. Collect Trainee Assessment Answer Sheets and Trainee Assessment Questionnaires (2 min.)	Note to Course Director: Collection of Trainee Assessment Questionnaires is optional. If the questionnaires are collected, they may be reused in Unit 15, *Closing*, saving on duplication costs.
IV. Direct Class to the Next Activity on the Course Agenda	
V. Grading and Evaluating Trainee Assessments	
A. An Answer Key to the Trainee Assessment is located at pages 1.2.7 and 1.2.8 The Answer Key should be used in scoring the exams.	
B. Score the following as *errors*:	
1. Any correct answer not marked by the trainee. 2. Any incorrect answer marked by the trainee as correct.	
C. Tally the following separately for each trainee:	
1. Total Number Correct Answers Not Marked	

LESSON OUTLINE | KEY POINTS & INSTRUCTOR GUIDE

The total number of correct answers marked is determined as the difference (154 - # not marked) and is an indicator of the trainee's knowledge of wastewater treatment operations.

2. Total Number of Incorrect Answers Marked

   The total number of incorrect answers marked is an indicator of misinformation the trainee has about wastewater treatment operations.

3. Subtract the Tally in C.2 from the Number of Correct Responses Given to Determine the Net Score.

D. Determine the class median, average and range for each tally and the net score in C above.

E. Experience has shown that trainees whose net score is less than 60 do not perform well in the course because they lack sufficient background knowledge to apply wastewater treatment principles to problem solving. The Course Director should interview each trainee scoring less than 60 on the Trainee Assessment and determine whether he/she will be permitted to remain in the course.

   The Course Director should approach this decision very cautiously because "expulsion" carries severe negative career implications for employed professionals. In lieu of expulsion the Course Director may wish to direct the trainee to the *Trainee Notebook* and other reference materials and assign him/her mandatory reading in advance of the classroom discussion and analysis of treatment operations and processes.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

Because poor performance on the Trainee Assessment correlates with poor performance in the course, the Course Director must assign grading of the Trainee Assessments a high priority. Grading should be completed before the second day classes begin. Individual trainee counseling should be conducted as early in the second day as possible.

F. Trainees are anxious to know how they performed on the Trainee Assessment and how their performances compared to the class norms.

It is recommended that the Course Director announce the class average, median and range for each tally and the net scores as the first item on the second day agenda.

Although not required, the Course Director may wish to post the individual scores so that trainees can see how well they did. The trainee social security account number should be used to identify individual scores. Trainee anonymity must be maintained to protect privacy and avoid embarrassment to individuals. An option is to provide the trainees' their scores orally and in private on an individual request basis.

Care must be taken to counsel trainees, particularly those who scored less than the class average, so that they do not become discouraged because of a low score. In the counseling session, stress that many questions reflect advanced levels of skills and knowledge in plant operations and that one purpose of the course is to provide a review of these skills and knowledge.

NAME: ______________________ SOCIAL SECURITY #: __________

TRAINEE ASSESSMENT - ANSWER SHEET KEY

TROUBLESHOOTING OPERATING AND MAINTENANCE PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Circle the correct letter(s)

1. [✓ a] b [✓ c] [✓ d] e
2. a [✓ b] c d
3. [✓ a] [✓ b] [✓ c] [✓ d] e
4. a [✓ b]
5. [✓ a] b c d
6. a [✓ b] c d
7. a [✓ b] c [✓ d] [✓ e]
8. [✓ a] [✓ b] c [✓ d] [✓ e]
9. [✓ a] [✓ b] [✓ c] d
10. [✓ a] b c d e f
11. [✓ a] [✓ b] [✓ c]
12. [✓ a] b c d
13. a [✓ b]
14. [✓ a] b c [✓ d] e [✓ f]
15. [✓ a] b c [✓ d] e
16. [✓ a] b [✓ c] d [✓ e]
17. [✓ a] [✓ b] c [✓ d] e
18. [✓ a] b c d e
19. a b c [✓ d] e
20. a b c d [✓ e]
21. [✓ a] b c [✓ d]
22. a [✓ b] c d e
23. [✓ a] b [✓ c] [✓ d] [✓ e]
24. [✓ a] b [✓ c] d e
25. a [✓ b] c d
26. [✓ a] b c d e
27. [✓ a] b c [✓ d] e
28. [✓ a] [✓ b] [✓ c] [✓ d] e
29. a b [✓ c] d e
30. [✓ a] b c d
31. a b [✓ c] d
32. [✓ a] [✓ b] [✓ c] d e
33. [✓ a] b c d
34. [✓ a] [✓ b] [✓ c] [✓ d] e
35. a [✓ b] c [✓ d] [✓ e]
36. a [✓ b] [✓ c] [✓ d] e
37. a [✓ b] [✓ c] d
38. [✓ a] b
39. a b [✓ c] d
40. [✓ a] [✓ b] [✓ c] [✓ d] [✓ e]

Answer Sheet Key
Page 2

NAME: ____________________

41. [✓ a] b c [✓ d] e
42. [✓ a] [✓ b] c [✓ d] [✓ e]
43. a [✓ b]
44. a [✓ b] c d
45. [✓ a] [✓ b] c [✓ d] e
46. a [✓ b]
47. a b [✓ c] [✓ d]
48. [✓ a] [✓ b] [✓ c] [✓ d]
49. [✓ a] [✓ b] c [✓ d] e f
50. [✓ a] [✓ b] [✓ c] [✓ d] e
51. a b c [✓ d] e
52. [✓ a] b [✓ c] [✓ d] e
53. [✓ a] b
54. [✓ a] b [✓ c] d e
55. [✓ a] b c d
56. a b c [✓ d] [✓ e]
57. a [✓ b] c d
58. a [✓ b] [✓ c] [✓ d] [✓ e]
59. a [✓ b] c d
60. a [✓ b]
61. [✓ a] b [✓ c] d
62. [✓ a] b [✓ c] [✓ d] [✓ e]
63. a b c d e f [✓ g]
64. a b c [✓ d] e
65. a [✓ b] [✓ c]
66. a b [✓ c] d [✓ e]
67. a [✓ b] c
68. [✓ a] b c [✓ d] e
69. [✓ a] b c d
70. a [✓ b] c [✓ d]
71. a b [✓ c] d e
72. [✓ a] b c d
73. [✓ a] [✓ b] [✓ c] [✓ d] [✓ e]
74. [✓ a] [✓ b] c
75. a [✓ b] d c

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 1: Overview

Lesson 2: Trainee Assessment

Trainee Handout Contents

Trainee Assessment Answer Sheet H1.2.1

Trainee Assessment H1.2.3

NAME: ______________________________ SOCIAL SECURITY #: __________

TRAINEE ASSESSMENT - ANSWER SHEET

TROUBLESHOOTING OPERATING AND MAINTENANCE PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Circle the correct letter(s):

1. a b c d e
2. a b c d
3. a b c d e
4. a b
5. a b c d
6. a b c d
7. a b c d e
8. a b c d e
9. a b c d
10. a b c d e f
11. a b c
12. a b c d
13. a b
14. a b c d e f
15. a b c d e
16. a b c d e
17. a b c d e
18. a b c d e
19. a b c d e
20. a b c d e
21. a b c d
22. a b c d e
23. a b c d e
24. a b c d e
25. a b c d
26. a b c d e
27. a b c d e
28. a b c d e
29. a b c d e
30. a b c d
31. a b c d
32. a b c d e
33. a b c d
34. a b c d e
35. a b c d e
36. a b c d e
37. a b c d
38. a b
39. a b c d
40. a b c d e

Answer Sheet
Page 2

NAME: ____________________

41. a b c d e
42. a b c d e
43. a b
44. a b c d
45. a b c d e
46. a b
47. a b c d
48. a b c d
49. a b c d e f
50. a b c d e
51. a b c d e
52. a b c d e
53. a b
54. a b c d e
55. a b c d
56. a b c d e
57. a b c d
58. a b c d e
59. a b c d
60. a b

61. a b c d
62. a b c d e
63. a b c d e f g
64. a b c d e
65. a b c
66. a b c d e
67. a b c
68. a b c d e
69. a b c d
70. a b c d
71. a b c d e
72. a b c d
73. a b c d e
74. a b c
75. a b c d

TRAINEE ASSESSMENT

TROUBLESHOOTING OPERATING AND MAINTENANCE PROBLEMS IN WASTEWATER TREATMENT FACILITIES

1. The activated sludge process:

    ___ a. requires aeration
    ___ b. requires activated carbon
    ___ c. is a biological process
    ___ d. usually follows primary sedimentation
    ___ e. is an anaerobic process

2. A BOD sample used to troubleshoot activated sludge plants should be collected before chlorination because:

    ___ a. chlorine interfers with the test causing results to be high
    ___ b. BOD is reduced by the chlorination process making the efficiency of other units appear higher
    ___ c. NPDES Permits require this
    ___ d. the BOD test cannot be run on chlorinated effluents

3. Sludge should be pumped from the primary clarifier to the digester several times a day to:

    ___ a. keep the pump from becoming clogged
    ___ b. prevent temporary overloading of the digester
    ___ c. maintain better conditions in the clarifier
    ___ d. permit thicker sludge pumping
    ___ e. prevent coning

4. If sludge removal rates are too low, then __________ conditions may develop in the secondary clarifier.

    ___ a. Aerobic
    ___ b. Anaerobic

5. Good supervision at wastewater treatment plants:

    ___ a. is often reflected by good employee attitudes
    ___ b. is not all that important if operators and mechanics have good technical training
    ___ c. probably won't affect the removal efficiency, but will create a cleaner, neater facility that everyone can be proud of
    ___ d. is something that comes naturally to skilled operators

6. In solving an operational problem at a treatment plant

___ a. there is always a "right" technical solution, it just takes time and experience to learn what it is
___ b. human errors may have to be corrected as well as mechanical errors
___ c. don't let the plant operator try to influence your judgment as to what the best solution is
___ d. standard textbooks in Sanitary Engineering are a major source of information

7. When the return sludge rate is too low, what happens?

___ a. The tank will not fill
___ b. There will be insufficient organisms to meet the waste load entering the aeration basin
___ c. The activated sludge in the aerator will starve
___ d. The activated sludge in the secondary clarifier could become septic
___ e. The sludge blanket in the secondary clarifier could become too high

8. What factors affect how well the mixed liquor suspended solids settle in the final clarifier?

___ a. Flow velocity and/or turbulence
___ b. Temperature
___ c. Laboratory analyses
___ d. Short circuiting
___ e. Aeration detention time

9. Stabilization pond scum rafts may be broken up by:

___ a. agitation with garden rakes
___ b. jets of water from pumps
___ c. the use of outboard motors on boats
___ d. breaking down the bindings

10. High volatile acid/alkalinity relationship in a digester may be caused by:

___ a. overloading the tank with organic material
___ b. pumping too thin a raw sludge
___ c. filling the tank too full
___ d. withdrawing supernatant
___ e. adding lime
___ f. underloading the tank with organic material

11. An operator should never be allowed to enter a room containing high concentrations of chlorine gas without

    ___ a. help standing by
    ___ b. notifying proper authorities
    ___ c. using a self-contained air or oxygen supply

12. If you were advised by your supervisor that the treatment plant at Community X was not operating to maximum design efficiency and he asked you to "troubleshoot" to see if better results could be obtained, the first thing you might do would be to

    ___ a. review your file records on the plant
    ___ b. call up the enforcement branch at the state pollution control agency
    ___ c. call up the plant operator to schedule a visit to the plant
    ___ d. visit the plant immediately

13. Primary clarifiers are designed to remove colloidal solids.

    ___ a. True
    ___ b. False

14. The active sludge process parameters which an operator can change directly are:

    ___ a. air rates
    ___ b. primary effluent total suspended solids
    ___ c. the ratio of free swimming to stalked ciliates
    ___ d. return sludge rates
    ___ e. influent load
    ___ f. excess solids wasted

15. The pilot flame in the digester waste gas burner should be checked daily to:

    ___ a. make sure it has not been blown out by the wind
    ___ b. prevent valuable gas from escaping
    ___ c. prevent odorous gas from escaping
    ___ d. prevent explosive conditions from developing
    ___ e. make sure proper temperatures are maintained in the digester

16. Large errors in laboratory tests may be caused by:

    ___ a. improper sampling
    ___ b. large samples
    ___ c. poor preservation
    ___ d. poor quality effluent
    ___ e. lack of mixing during compositing

17. In operating a trickling filter the operator should be trained to:

___ a. adjust the process to obtain the best possible results for the least cost
___ b. use the lowest recirculation rates that will yield good results to conserve power
___ c. rotate the distributor as fast as possible to better spray settled wastewater over the media
___ d. maintain aerobic conditions in the filter
___ e. bubble oxygen up through the filter

18. The maximum change in excess sludge wasting rates should be about:

___ a. 10-20% per day
___ b. 20-40% per day
___ c. 40-60% per day
___ d. 60-80% per day
___ e. 100% or more per day

19. The temperature of a digester should not be changed more than one degree per day to:

___ a. avoid excessive heat losses
___ b. avoid overloading of the heat exchanger
___ c. allow the walls of the digester time to expand and contract
___ d. allow the organisms in the digester time to adjust to temperature changes
___ e. allow time for heating gas to be produced in the digester

20. Acceptance of the troubleshooter by the plant operator and supervisors is:

___ a. unimportant
___ b. a plant problem
___ c. impossible
___ d. aided by troubleshooting
___ e. essential

21. Sprinkler clogging on a spray irrigation system can be cured by:

___ a. running a mild acid solution through the distribution system
___ b. "blowing out" the solids by suddenly raising the pressure
___ c. adding more pumps to the system
___ d. periodic draining and flushing of the system

22. When operating an activated sludge plant, which TSS concentration is most important to process control?

___ a. Primary effluent
___ b. Aerator mixed liquor
___ c. Return sludge
___ d. Final clarifier effluent
___ e. Plant influent

23. To correct an odor problem in a trickling filter the operator should:

___ a. take corrective action immediately
___ b. shut off flow to the filter
___ c. try to maintain aerobic conditions
___ d. check ventilation in the filter
___ e. increase recirculation rate

24. Package plants usually:

___ a. operate the aeration device continuously
___ b. have an operator at the plant 24 hours a day
___ c. waste sludge out the effluent, but shouldn't when properly operated
___ d. have an extensive lab testing program
___ e. are affected by none of these

25. Which of the following are not responsibilities normally required of treatment plant operators?

___ a. Public relations
___ b. Plant design and modification
___ c. Supervision of plant personnel
___ d. Plant safety

26. A scum blanket in a digester is best broken up by:

___ a. vigorously mixing the digester contents from bottom to top
___ b. burning
___ c. use of long poles
___ d. an ax
___ e. adding enzymes

27. Lagoon performance can be indicated by what tests?

___ a. pH
___ b. Carbon dioxide
___ c. Methane
___ d. Dissolved oxygen
___ e. Hardness

28. If a flow meter does not read properly, what items should be checked as potential causes of error?

___ a. Installation of sensor and readout devices
___ b. Restrictions in the sensor and transmitter
___ c. Power supply to instruments
___ d. Check instruments according to manufacturer's instructions
___ e. Blow the transmission lines out with high pressure air

29. Operator training is:

___ a. a luxury that most public sewerage agencies cannot afford
___ b. best done through correspondence courses
___ c. necessary for operators to upgrade needed skills
___ d. best done on the job
___ e. one goal in a technical assistance project

30. In spray irrigation and other land treatment methods, the system operator need not worry about:

___ a. final effluent color
___ b. nutrient levels applied to crops
___ c. weed killers
___ d. odors

31. Chemicals commonly added for coagulation are:

___ a. salts of potassium and sodium
___ b. chlorine and iodine
___ c. salts of iron and aluminum
___ d. activated carbon

32. What could be happening if gas production in a digester starts decreasing?

___ a. The volatile acid/alkalinity relationship is increased
___ b. The raw sludge volume fed to the digester is decreasing
___ c. The raw sludge volume fed to the digester is excessive
___ d. The scum blanket is breaking up
___ e. The volatile acid/alkalinity relationship is decreasing

33. Reducing the return sludge flow rate for an activated sludge system which has a good settling sludge will:

___ a. increase the hydraulic detention time in the aeration basin
___ b. decrease the sludge detention time in the aeration basin
___ c. cause the return sludge concentration to decrease
___ d. have no effect on process performance

34. What items would you check if an activated sludge plant becomes upset?

___ a. Influent temperature
___ b. Daily flow rates
___ c. BOD loadings
___ d. Digester operation
___ e. Chlorinator

35. Lagoons may not operate properly if:

___ a. the influent organic matter content fluctuates considerably every few days
___ b. temperature stays below freezing for a long time
___ c. there is no scum blanket
___ d. the influent contains a powerful fungicide in significant quantities
___ e. the influent has a high sulfur content

36. Causes of sludge bulking include:

___ a. bulk of sludge too large
___ b. air supply too low
___ c. loading rate too high
___ d. aeration period too short
___ e. sludge going septic in secondary clarifier

37. Industrial waste materials which are not considered as compatible pollutants for municipal treatment plants include:

___ a. chemical oxygen demand
___ b. heavy metals
___ c. fats, oils and greases
___ d. nitrogen and phosphorous compounds

38. It is important to listen carefully to various plant personnel in determining how to proceed in evaluating and solving problems.

___ a. True
___ b. False

39. Land treatment:

___ a. is never appropriate in a humid climate
___ b. should never be used in areas subject to below freezing temperatures
___ c. requires careful maintenance and operation
___ d. is not appropriate treatment process under new federal water pollution control laws

40. The effectiveness of the organisms in the aerator depends on the:

___ a. temperature
___ b. pH
___ c. presence of inhibiting substances
___ d. characteristics of food supply
___ e. hydraulic detention time in the aeration basin

41. Which of the following statements regarding aerobic digesters are true?

___ a. They are simpler to operate than anaerobic digesters
___ b. Dissolved oxygen must be maintained above 4 mg/l
___ c. They are most commonly found in very large treatment plants
___ d. The normal detention time is 15-25 days
___ e. Sludge should be introduced once or twice a week

42. A good troubleshooter's attitude will convey

___ a. efficiency
___ b. helpfulness
___ c. familiarity
___ d. confidence
___ e. friendliness

43. The answers from the total solids and suspended solids tests are always the same.

___ a. True
___ b. False

44. Which is probably an indicator of a good collection system?

___ a. Excessive grit in treatment plant influent
___ b. High temperature sewage influent
___ c. Septic odors
___ d. Surcharges and by-passes of flows

45. Why should all of the diffusers in an aeration tank be cleaned at once?

___ a. To get the job done in a hurry
___ b. So the air will flow evenly out all of the diffusers
___ c. To improve step-feed aeration
___ d. So the plant won't use too much air
___ e. None of these

46. Aerobic digesters are more susceptible to upset than anaerobic digesters.

___ a. True
___ b. False

47. If water is flowing off of a spray irrigation application area, the problem might be solved by:

- ___ a. planting crops closer together
- ___ b. adding fertilizers to the flow of effluent
- ___ c. placing sprinklers further apart
- ___ d. terracing or modifying contours of irrigated area

48. Chemical clarification is used to enhance the removal of:

- ___ a. phosphorous
- ___ b. heavy metals
- ___ c. colloidal solids
- ___ d. materials less dense than water

49. Results from the settleability test of activated sludge solids may be used to:

- ___ a. calculate SVI
- ___ b. calculate return sludge rates
- ___ c. calculate sludge age
- ___ d. determine ability of solids to separate from liquid in final clarifier
- ___ e. calculate mixed liquor suspended solids
- ___ f. calculate waste sludge rates

50. Dissolved oxygen in a lagoon is increased by:

- ___ a. surface aerators
- ___ b. photosynthesis
- ___ c. wind action
- ___ d. algae liberating oxygen from the water molecule
- ___ e. sludge gases from bottom deposits floating to the surface

51. Successful trickling filter operation depends upon:

- ___ a. maintenance of a chlorine residual in the effluent
- ___ b. washing slime off the filter media
- ___ c. preventing sludge bulking
- ___ d. maintenance of a good growth of organisms on the filter media
- ___ e. filtering the solids out of the wastewater

52. Sludge thickeners work on the principles of:

- ___ a. flotation
- ___ b. filtration
- ___ c. gravity settling
- ___ d. centrifugal force
- ___ e. anaerobic bacteria

53. The two principal elements of the troubleshooting process used by troubleshooters are problem identification and problem solving.

___ a. True
___ b. False

54. If results of the MLSS settling test show that the sludge is beginning to settle faster, then:

___ a. increase sludge return rate
___ b. decrease sludge return rate
___ c. increase sludge wasting rate
___ d. decrease sludge wasting rate
___ e. make no changes

55. As a troubleshooter, you should:

___ a. be aware of the overall community's concern and goals affecting wastewater treatment
___ b. not be concerned with outside-the-plant problems
___ c. restrict your evaluation to in-plant findings
___ d. send out news releases on your findings

56. Measuring flow in treatment plants:

___ a. is not necessary
___ b. is a luxury most troubleshooters don't have to worry about
___ c. is generally accurate and troublefree
___ d. can be the key to troubleshooting several types of in-plant problems
___ e. can be done with a variety of temporary expedients if necessary

57. The main purpose of this course is to:

___ a. make you a better wastewater treatment plant operator
___ b. help you learn how to evaluate and assist in solving plant problems
___ c. help you learn ways to have all plant personnel like you
___ d. teach you how to design treatment plants

58. Problems associated with trickling filters include:

___ a. bulking
___ b. filter files
___ c. clogging
___ d. turbid effluent
___ e. snails

59. Short-circuiting in a final sedimentation process:

___ a. is probably caused by mechanical failures
___ b. usually represents a hydraulic deficiency of design or operation
___ c. increases efficiency by facilitating rapid movement of treatment plant effluent
___ d. has no effect on plant performance

60. A troubleshooter shouldn't offer suggestions unless he is asked for help.

___ a. True
___ b. False

61. If hydraulic load to an activated sludge plant increases but return and waste rates are not changed, what changes in process control parameters would be observed?

___ a. MLSS respiration rate (specific oxygen uptake rate) would increase
___ b. MLSS settling rate would increase
___ c. Final clarifier sludge blanket would rise
___ d. None of the parameters would change

62. Chlorinators should be located:

___ a. near the point of application
___ b. outdoors
___ c. in a separate room
___ d. in a room that will not allow chlorine to leak into rooms where operators work or where controls and equipment are located
___ e. in an adequately heated room

63. Which of the following parameters is best for operational control of the activated sludge process?

___ a. F/M
___ b. MCRT
___ c. MLSS Respiration Rate (specific oxygen uptake rate)
___ d. MLSS settleability
___ e. Final clarifier sludge blanket depth
___ f. MLSS concentration
___ g. All must be monitored to achieve optimum control

64. While you are troubleshooting a plant, the operator complains of several design defects which make the plant difficult to operate. Your response is:

___ a. deny that design engineers ever make errors
___ b. accept that deficiences may exist and report back to your boss and the design engineer
___ c. blame the problem on EPA construction grant program regulations
___ d. explain that tradeoffs have to be made during design and the reasons for them, then do b
___ e. Ignore him. Operators always blame the design engineer.

65. Old, overoxidized, underloaded activated sludges:

___ a. settle slowly but produce clear effluents
___ b. settle rapidly leaving a turbid supernatant
___ c. produce nitrified effluents and tend to rise if left in the final clarifier too long

66. Increasing the return sludge flow rate in an activated sludge system with a normally settling sludge will:

___ a. increase the F/M
___ b. decrease the F/M
___ c. not change the F/M
___ d. increase the MCRT
___ e. probably cause the sludge to settle more slowly

67. The F/M, MCRT and return sludge rate used as a design basis:

___ a. always yield most efficient performance and should be strictly maintained by the operator
___ b. offer a good starting point for determining parameter values to achieve optimum performance
___ c. are meaningless theoretical numbers which have no practical significance and should be ignored

68. Sludge is observed to accumulate in the final clarifier. This may be caused by:

___ a. plugged sludge collectors, return pumps or waste pumps
___ b. too high a return rate
___ c. excessive solids wasting
___ d. overloaded clarifier
___ e. none of the above

69. The first step in evaluating a treatment plant during the initial site visit is:

___ a. check all equipment to assure that mechanically it is operating properly
___ b. collect samples and begin to run tests
___ c. immediately change something to impress the operator
___ d. all of the above

70. The correct operational response to a slowly settling sludge which is not washing out of the final clarifier is to:

___ a. increase return sludge flow rate
___ b. decrease return sludge flow rate
___ c. increase sludge wasting
___ d. decrease sludge wasting

71. Thick, billowing white foam on the aeration basin usually indicates:

___ a. an old sludge
___ b. a normal condition
___ c. a young sludge
___ d. has no meaning to the troubleshooter
___ e. a detergent problem

72. The most frequent cause of poor treatment system performance is:

___ a. the operator's lack of understanding of treatment principles and his failure to properly apply process control concepts
___ b. design engineers do not understand operation and maintenance requirements and design plants which cannot be operated
___ c. communities fail to write and enforce effective sewer use control ordinances permitting uncontrolled discharge of harmful industrial wastes
___ d. the state and regulatory agencies place unreasonable demands on treatment facilities and set unrealistic discharge standards which cannot be achieved

73. Which of the following flow rates must be measured if the operator is to control the plant properly?

___ a. Influent
___ b. Effluent
___ c. Return sludge
___ d. Waste sludge
___ e. Air

74. An aerobic biological treatment system performs well during the winter months. During the summer months the effluent becomes turbid, effluent BOD increases and is erratic, and chlorine demand increases. This observation indicates that the plant is probably processing a partially nitrified effluent. To improve plant performance the operator may:

___ a. decrease MCRT, increase F/M and decrease aeration basin detention time to take the plant out of nitrification
___ b. increase MCRT, decrease F/M and increase aeration basin detention time to produce a fully nitrified effluent
___ c. do nothing. This is a normal situation for a slightly underloaded plant.

75. Which of the following activated sludge processes offer the greatest flexibility for the operator to respond to varying influent conditions?

___ a. Conventional
___ b. Step feed
___ c. Extended aeration
___ d. Contact stabilization

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 1: Overview

Lesson 3: Significance of Plant O & M

Lesson 3 of 4 lessons Recommended Time: 30 minutes

Purpose: The lesson reviews survey data which show that inadequate plant O & M is a significant cause of poor performance at wastewater treatment facilities and identifies other factors which contribute to poor plant performance. The lesson shows that improved plant performance would contribute substantially to attainment of national water quality improvement goals. The lesson establishes in-plant technical assistance as an essential component of comprehensive federal, state and local programs to improve treatment facility performance.

Trainee Entry Level Behavior: Trainees will have completed Unit 1, Lessons 1 and 2.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. State the water quality objectives established in the Federal Water Pollution Control Act (PL 92-500 and PL 95-217);
2. List and discuss EPA and state agency water pollution control program elements mandated by PL 92-500 and PL 95-217;
3. List and discuss at least five factors which may contribute to poor plant performance;
4. Describe how in-plant technical assistance and troubleshooting may be used to improve treatment plant performance;
5. Explain why cooperation between federal, state and local pollution control agencies, private sector consulting firms and wastewater treatment facility owners and operators is essential to attainment of water pollution control program objectives;

6. Describe the trainee's role in water pollution control program implementation and explain how he/she as an individual can contribute to achieving improved water quality through improved wastewater treatment plant performance;

7. (Optional) Describe the national and regional distribution of wastewater treatment facilities by type of treatment and explain how the distribution of facilities affects the trainee's job responsibilities.

Instructional Approach: Illustrated lecture with trainee discussion, questions and answers.

It is recommended that the instructor follow the lesson outline provided. The instructor should modify the lesson outline as necessary to relate content to the trainees and their job responsibilities.

Lesson Schedule: Within the 30 minutes allocated to this lesson, the instructor should observe the following schedule in presenting the lesson outline:

TIME	SUBJECT
0 - 10 minutes	Relationship of Troubleshooting to Federal Water Pollution Control Legislation and Programs
10 - 20 minutes	Magnitude of the O & M Problem
20 - 30 minutes	Factors Affecting Plant Performance

Trainee Materials Used in Lesson: *Trainee Notebook*, pages T1.3.1 - T1.3.5.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 1, Lesson 3, pages 1.3.1 - 1.3.22.

2. Slides 179.2/1.3.1 - 179.2/1.3.34

Instructor Materials Recommended for Development:

1. Locale specific survey results documenting local factors which affect plant performance.

2. Materials explaining organization specific policies, procedures or programs which impact technical assistance and troubleshooting program implementation.

Additional Instructor References:

1. Azan, K.M., and Boyko, B.I., "Identification of Problem Areas in Water Pollution Control Plants," Research Report No. 15, Ontario Ministry of the Environment, 1973.

2, Evans, Francis L. III, "Summary of National Operational and Maintenance Cause and Effect Survey," *Technology Transfer*, Environmental Protection Agency, Cincinnati, Ohio, July, 1979.

3. Gilbert, W.G., "Relation of Operation and Maintenance to Treatment Plant Efficiency," *Journal Water Pollution Control Federation*, *48*, July, 1976, pp. 1822-1833.

4. Hegg, Bob A., Rakness, Kerwin L. and Schultz, James R., "Evaluation of Operation and Maintenance Factors Limiting Municipal Wastewater Treatment Plant Performance," *Journal Water Pollution Control Federation*, *50*, March, 1978, Part I, pp. 419-426.

5. Hill, W. R., Regan, T.M. and Zickefoose, C.S., "Operation and Maintenance of Water Pollution Control Facilities: A WPCF White Paper," *Journal Water Pollution Control Federation*, *51*, May, 1979, pp. 899-906.

6. The Federal Water Pollution Control Act (PL 92-500) as amended by the Clean Water Act of 1977 (PL 95-217).

Classroom Set-Up: As specified in Unit 1, Lesson 1.

LESSON OUTLINE

I. Perspective of Troubleshooting Plant Problems in Relation to the Federal Water Pollution Control Program (5 min.)

A. Explain to class that the purpose of this section is to relate troubleshooting plant problems to the larger elements of the federal water pollution control program.

B. Note to class that the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) and the Clean Water Act Amendments of 1976 (PL 95-217) establish national goals to:

1. Eliminate discharge of pollutants by 1985;
2. Achieve fishable and swimmable waters by 1983.

C. To achieve the above goals the Acts provide programs for:

1. Establishing water quality standards in cooperation with the states
2. Areawide planning
3. Federal financial assistance to construct publicly owned treatment works
4. Point source discharge control through the National Pollutant Discharge Elimination System (NPDES) Permit program

Note that Federal construction grants and the NPDES permit programs are the major

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/1.3.1
Slide 179.2/1.3.1 is a BLANK used to blacken screen.

Use Slide 179.2/1.3.2
(Also available as print master to make overhead transparency)

Slide 179.2/1.3.2 reads:

"PL 92-500 (1972) and PL 95-217 (1976)

Goals
- No Discharge by 1985
- Fishable and Swimmable Waters by 1983"

Use Slide 179.2/1.3.3
(also available as print master to make overhead transparency)

Slide 179.2/1.3.3 reads:
"National Water Quality Control Program Elements

- Water Quality Standards
- Areawide Planning
- Construction Grants
- NPDES Permits

elements being used to achieve water quality goals.

a. The construction grants program provides assistance to design and construct treatment facilities capable of providing at least secondary treatment (30 mg/l BOD_5 and 30 mg/l TSS in effluent). In some cases more advanced treatment for nutrient control is provided.

b. NPDES permits define the acceptable discharge from all point sources, provide tools to monitor the performance of individual point sources and take corrective measures as appropriate.

Of these, NPDES provides the tools to maintain water quality once planning and construction are completed.

D. If the NPDES permit program is to be successful, we must have:

1. Adequate treatment facilities

Treatment facilities must be designed and constructed to provide a physical plant capable of treating wastewater to produce high quality effluents consistently. This applies not only to new construction, but also to upgrade, rehabilitation or enlarging existing facilities to meet more stringent standards. As a result plants are/will be more complex and more difficult to operate and maintain. The design must provide for operational flexibility and controllability if the plants are to perform consistently.

Use Slide 179.2/1.3.4 (also available as print master to make overhead transparency)

Slide 179.2/1.3.4 reads:

"TO MAKE NPDES WORK - WE NEED

- ADEQUATE TREATMENT FACILITIES
- EFFICIENT PLANT OPERATIONS
- MONITORING AND INSPECTION
  - FEDERAL
  - STATE
  - LOCAL"

2. Efficient Plant Operations

   An adequate physical plant doesn't insure good performance. The physical plant must be operated correctly and maintained regularly if it is to comply with discharge standards. This requires operations personnel who know their jobs and who perform their jobs well. Equally important, it requires that owners provide competent management and adequate financial support for the treatment plant. It also requires a capability to assist plants which are not performing well.

3. Monitoring and Inspection

   In addition to the "self-monitoring" required by the NPDES permit program, there must be oversight from federal and state regulatory agencies to confirm that treatment plants are being operated and maintained properly.

   The first line of responsibility for monitoring and inspection is at the local level where the owner is responsible for day-to-day monitoring and compliance.

   Federal and state regulatory agencies must have a capability to properly review and evaluate "self-monitoring" reports and to follow-up with on-site inspection and monitoring. Inspection and monitoring personnel must be qualified and competent to gather appropriate data, to evaluate the results and to follow-up to achieve compliance from non-compliers.

LESSON OUTLINE

E. If monitoring and inspection activities find that a plant is not in compliance, there must be appropriate follow-up to bring the facility into compliance. Follow-up consists of three major components:

1. Evaluation to determine the cause for non-compliance
2. Corrective Action at local level to eliminate the cause for non-compliance. May involve federal and state agencies directly if new construction is required.
3. Enforcement as back-up if corrective actions are not taken at local level.

This implies that there must be cooperation and coordinated action between federal, state and local pollution control personnel to identify the causes of non-compliance, recommend appropriate corrective actions, implement the corrective actions and follow-up to determine the success of the corrective action program.

F. All the above establishes the case for an effective *Troubleshooting* capability at local, state and federal levels. Troubleshooting capability can be summarized in the six points shown on Slide 179.2/1.3.6.

Several studies have shown that many local pollution control agencies (treatment plants) need *technical assistance* to do the things shown on the slide. The plant personnel may seek *technical assistance* from

1. Other Plant Operators
2. Consultants
3. State Agencies
4. Federal Agencies

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/1.3.5 (also available as print master to make overhead transparency)

Slide 179.2/1.3.5 reads:

"Uses of Monitoring and Inspection Findings

- Evaluation
  Local, state, federal
- Corrective Action
  Local
- Enforcement
  Federal, State"

Use Slide 179.2/1.3.6 (also available as print master to make overhead transparency)

Slide 179.2/1.3.6 reads:

"Pollution Control Personnel Must Be Able To:

- Evaluate Plant Performance
- Identify Performance Deficiencies
- Determine Causes
- Recommend Corrective Action
- Implement Corrective Action
- Follow-Up Corrective Action"

LESSON OUTLINE

G. Note that this course is designed to assist water pollution control personnel develop troubleshooting skills by:

1. Providing training in a systematic approach to plant evaluation and problem solving called the *Process of Troubleshooting;*

2. Providing a technical review of plant operations;

3. Providing exposure to realistic operating problems;

4. Applying the *process of troubleshooting* to evaluation and solution of operating problems;

5. Stressing the need for local, state and federal cooperation in technical assistance program implementation; and

6. Providing an opportunity to practice communication and other interpersonal skills.

II. Importance of Cooperation (5 min)

Many levels of government as well as the private sector are involved in a successful program to improve plant performance through technical assistance and troubleshooting efforts. The following section discusses some of the responsibilities of each agent who may be involved and illustrates why cooperation is essential to a successful technical assistance effort.

A. Owner's Responsibility

1. Owner may be:

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/1.3.7
(also available as print master to make overhead transparency)

Slide 179.2/1.3.7 reads:

"Course Purposes

- Train in Process of Troubleshooting
- Review Plant Operations
- Apply Process of Troubleshooting to Realistic Problems
- Stress Cooperative Relationships
- Improve Communication Skills"

Use Slide 179.2/1.3.8
(also available as print master to make overhead transparency)

LESSON OUTLINE

a. Private (industry, developer, etc.)

b. Government or Quasi-Government Agency
    (1) State or federal
    (2) Local
        (a) Municipality
        (b) Sewage Agency or authority

NOTE: This course will stress troubleshooting at publicly owned treatment works with local government or a sewerage agency or authority as the owner.

2. Owner's responsibilities include:

a. Operate the plant with ultimate responsibility and accountability for the plant's performance.

b. Receptive to technical assistance project with responsibility to seek assistance when needed by:

    (1) Retaining an operations consultant or
    (2) Accepting state or federal technical assistance

c. Provide an adequately trained staff to operate the facility. The technical assistance project may be directed toward training plant staff to upgrade capabilities.

d. Provide financing to upgrade performance.

    (1) Adequate O & M budget
    (2) Capital improvements to make plant more operable, increase

KEY POINTS & INSTRUCTOR GUIDE

Slide 179.2/1.3.8 reads:

"Owner's Role

- Operate Plant
- Accept Technical Assistance
- Train Staff
- Fund Improvements
    - Operational
    - Facility Modification"

LESSON OUTLINE

capacity, correct deficiencies, replace equipment, etc.

B. State Government's Responsibilities

1. State should provide an adequate field operations staff who are qualified (trained) to inspect, monitor and provide technical assistance when needed. Many smaller communities have neither the in-house capability nor the financial resources to retain a qualified consultant. Thus, the state may become the primary technical resource to assist the smaller community.

2. State should assure that there is an adequate training program available to operators. Many states conduct the operator training program. All states have operator certification programs. State field personnel provide on-the-job training with each inspection or monitoring visit. This may be a recognized part of the state field operations program or may be an informal activity which occurs because the "state inspector" is there.

3. Compliance assurance functions range from initial permit issuance or renewal to determining actions to be taken to bring a facility into compliance. A balance must be struck between enforcement and assistance to achieve the most effective compliance assurance strategy.

4. Almost all states provide plans and specification review for major construction at wastewater treatment facilities. Many states have state grant programs to assist communities with design and construction of new

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/1.3.9
(also available as print master to make overhead transparency)

Slide 179.2/1.3.9 reads:

"State's Role

- Field Personnel
  - Inspection
  - Monitoring
  - Technical Assistance
- Operator Training and Certification
- Compliance Assurance
  - Issue Permits
  - Enforcement
  - Assistance
- Construction Support
  - Plans & Specs Review
  - Grants"

treatment works. Some provide assistance for facility modification or upgrading. The EPA policy is to delegate federal construction grants program functions to the states. An "operations review" should be an integral part of the state construction support functions.

C. Federal Government's Responsibilities

1. The Environmental Protection Agency has the lead responsibility at Federal level for water pollution control programs.
2. The direct role of EPA is decreasing as programs are delegated to the states (NPDES Permit authority, Construction grants, etc.) but the EPA's role to provide program guidance and assistance to states is increasing.
3. Because of resources available and its national responsibility, the EPA must continue to develop and disseminate water pollution control program guidance. Such program guidance must include plant operations and other operational considerations. EPA continues to be a primary resource for technical manuals on plant operations and a principal resource for training through the National Training and Operational Technology Center and the Technology Transfer programs at Cincinnati.
4. EPA continues to be the major source for construction funding through the grants program. Tied to this is the continuing role to provide design guidelines and standards which consider plant operations. The O & M

Use Slide 179.2/1.3.10 (also available as print master to make overhead transparency)

Slide 179.2/1.3.10 reads:

"Federal Role

- Technical Assistance
  - Program Guidance
  - Technical Manuals
  - Training
- Construction Support
  - Grants
  - Design Guidance
  - O & M Manuals
- Compliance Assurance
  - Guidance
  - Inspection
  - Technical Assistance"

LESSON OUTLINE

manual provides plant specific operational guidance for facilities constructed with federal grant funds. Plant start-up assistance and start-up training are eligible for funding support under the grants program

5. EPA monitors the state programs in compliance assurance and continues to inspect major discharges. The EPA is a technical resource to states and local government and can provide direct assistance on request.

D. Private Sector Consultant's Responsibilities

   1. Consultants must design facilities which are operable and controllable. They must also design retrofits to correct deficiencies.

   2. Consultants must provide accurate and usable operations guidance in the O & M manual.

   3. Consultants must plan and implement start-up programs to include adequate start-up training for operations personnel.

   4. Consultants will play an increasing role in providing in-plant technical assistance to facilities having operational problems.

   5. Many communities now contract for operational services at wastewater treatment facilities. The consulting profession will be the primary beneficiary of this trend if the industry is prepared to assume these responsibilities.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/1.3.11
(also available as print master to make overhead transparency)

Slide 179.2/1.3.11 reads:

"Consultant's Role

- Design
- Start-up
- Technical Assistance
- Operational Services"

LESSON OUTLINE

E. Discussion

Invite the class to expound on the points made relative to the several agency roles identified. Focus on interactions between the four groups identified with stress on the need for all groups to work together to assure adequate O & M of treatment works.

III. Magnitude of the O & M Problem (10 min)

A. Distribution by Types and Sizes of Treatment Plants, Nationally and By EPA Region (1975 data)

1. National distribution by type of treatment

   a. Total plants - 23, 986

   b. Types of plants

      (1) Activated Sludge - 2,111 (9% of total)

      (2) Extended Aeration - 2,483 (10% of total)

      (3) Trickling Filters - 3,565 (15% of total)

      (4) Oxidation Ponds - 5,464 (23% of total)

KEY POINTS & INSTRUCTOR GUIDE

Note to Instructor: This section develops by summarizing the distribution of wastewater treatment plants nationally and by EPA Region. Results of an EPA survey of the performance of plants built with Federal construction grants are presented to document the severity of the O & M problem.

Use Slide 179.2/1.3.12

Slide 179.2/1.3.12 is a pie chart showing distribution of treatment plants by type of treatment. Data are summarized in the Lesson Outline.

LESSON OUTLINE

   (5) Other Secondary - 3,580 (15% of total)

   (6) Primary or Intermediate - 2,921 (12% of total)

   (7) Tertiary - 1,016 (4% of total)

   (8) None or Minor - 2,846 (12% of total)

  c. Significant feature is that 48% of total are extended aeration, oxidation ponds and trickling filters indicating that there is a large number of smaller facilities.

2. National distribution by population served and type of treatment

  a. Total population served - 159,000,000

  b. Total number of plants - 23,986

  c. Population served by type of treatment

   (1) Activated Sludge - 50,000,000 (31% of total)

   (2) Primary/Intermediate - 43,000,000 (27% of total)

   (3) Trickling Filter - 31,000,000 (20% of total)

   (4) Oxidation Ponds - 8,000,000 (5% of total)

   (5) Extended Aeration - 5,000,000 (3% of total)

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/1.3.13

Slide 179.2/1.3.13 is a bar chart showing distribution by population served and type of treatment. Data are summarized in the Lesson Outline.

LESSON OUTLINE

(6) Other Secondary - 15,000,000
(9% of total)

(7) Tertiary - 3,000,000
(2% of total)

(8) None or Minor - 4,000,000
(3% of total)

c. Confirms conclusion that bulk of plants are small and that larger facilities tend to be activated sludge plants.

3. Distribution by EPA Region

a. Type of treatment

Select slide or slides for appropriate Region or Regions

KEY POINTS & INSTRUCTOR GUIDE

Slide 179.2/1.3.14
Region I - Boston

Slide 179.2/1.3.15
Region II - New York

Slide 179.2/1.3.16
Region III - Philadelphia

Slide 179.2/1.3.17
Region IV - Atlanta

Slide 179.2/1.3.18
Region V - Chicago

Slide 179.2/1.3.19
Region VI - Dallas

Slide 179.2/1.3.20
Region VII - Kansas City

Slide 179.2/1.3.21
Region VIII - Denver

Slide 179.2/1.3.22
Region IX - San Francisco

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	Slide 179.2/1.3.23 Region X - Seattle
b. Population served by type of treatment Select slide or slides for appropriate Region or Regions	Slide 179.2/1.3.24 Region I - Boston Slide 179.2/1.3.25 Region II - New York Slide 179.2/1.3.26 Region III - Philadelphia Slide 179.2/1.3.27 Region IV - Atlanta Slide 179.2/1.3.28 Region V - Chicago Slide 179.2/1.3.29 Region VI - Dallas Slide 179.2/1.3.30 Region VII - Kansas City Slide 179.2/1.3.31 Region VIII - Denver Slide 179.2/1.3.32 Region IX - San Francisco Slide 179.2/1.3.33 Region X - Seattle
Advance to Slide 179.2/1.3.34	Use Slide 179.2/1.3.34 Slide 179.2/1.3.34 is a Blank slide used to blacken the screen so that the lights can be raised to permit trainees to refer to the *Trainee Notebook*.

B. Results of EPA survey of Performance of Wastewater Treatment Facilities

1. The purpose of this session is to indicate the nature of the O & M problem and the potential benefits which may derive from improved plant O & M.

2. Plant Performance

   a. Less than half of secondary facilities are meeting secondary effluent requirements.

   b. Trickling filter plants have more difficulty meeting requirements than do activated sludge plants.

   c. 4,400 secondary plants may not be in compliance.

3. Marginal Plants

   a. 20 percent of all secondary plants - up to 1,700 nationally, are classified as "marginal performers."

   b. Marginal performers - do not meet secondary requirements, but

   c. They can meet secondary requirements without significant investments in new construction, thus

   d. Some 1,700 plants could achieve requirements through O & M and minor plant modifications.

4. Laboratory Facilities

Refer class to page T1.3.1 of the *Trainee Notebook*. This page is titled "Summary of Survey of Federally Funded Treatment Facilities."

a. Many plants had inadequate lab facilities, thus

b. Many facilities could not provide adequate operational data.

c. Testing for process control is low due to inadequate lab facilities.

d. Illinois Survey - With an adequate lab plant performance can be increased by 20 percent.

5. Other Factors

a. Plants with good maintenance management programs perform better.

b. Attention to routine training, short courses, etc., has been lacking.

6. Survey Conclusions

a. Improved O & M practices, laboratory facilities and training can lead to *major* improvement in plant performance and will enable an additional 20 percent of all secondary plants to meet existing requirements.

b. Based on EPA experience direct operational assistance to plant operators can result in significant improvement in plant performance.

c. Assistance programs exemplified by work of the National Training and Operational Technology Center, EPA Cincinnati - considerable success in providing control methodologies for activated sludge facilities with subsequent improvement in plant performance.

Note: Refer students to papers by Gilbert listed in *Trainee Notebook* under references for Unit 1.

Guide: Attempt to establish class discussion on the Survey results and conclusions.

LESSON OUTLINE

KEY POINTS &
INSTRUCTOR GUIDE

7. Significance

   a. As a result of EPA Survey and conclusions, troubleshooting and O & M technical assistance must be stressed as an important part of the overall clean-up effort for water pollution.

III. Factors Affecting Plant Performance (10 min.)

Refer class to page T1.3.3 in *Trainee Notebook*. This page is titled "Summary of Operation and Maintenance Factors Limiting Municipal Wastewater Treatment Plant Performance."

A. During 1976-1978 the USEPA, Cincinnati sponsored an extensive survey of wastewater treatment facilities to determine the factors which limit performance. The results below summarize the findings of Hegg, *et al* (see references). The survey identified 60 factors which limit performance. The following section summarizes the most frequently occurring factors.

B. Summary of Research Findings

   1. Causes of Poor Performance

      a. Poor operator skills

      b. Inoperable equipment due to poor maintenance and/or poor design

      c. Inadequate testing - especially process control testing. (Note that many labs are designed for NPDES monitoring test, not process control tests.)

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

2. Factors Limiting Plant Performance
    a. Poor application of control concepts and testing to process control by operators
    b. Lack of understanding of wastewater treatment principles by operators
    c. Improper technical guidance from design consultants, regulatory agency personnel, operator trainers, etc.
    d. Inadequate process control testing
    e. Limited process flexibility or controllability
    f. Insufficient solids handling capacity
    g. Improper design
3. Needs to Improve Plant Performance
    a. Better trained operators
    b. Better trained technical support people
    c. Improved technical assistance
    d. Design and construction to consider operability
4. Solutions
    a. Quality operator training programs
    b. In-plant technical assistance
    c. Design and construction based on:

LESSON OUTLINE

(1) Feedback from operations
(2) Better design criteria
(3) Regulations and guidelines

C. Conclusions

1. Many factors limit performance at any given wastewater treatment facility.

2. If the plant is to perform at peak efficiency, all the factors limiting performance must be eliminated.

3. A broadly defined comprehensive corrective action program is required to eliminate all the factors which limit performance. Elements of a comprehensive corrective action program include:

    a. Correction of operational factors

        (1) Define optimum control strategy for the plant
        (2) Train the operators
        (3) Provide in-plant assistance

    b. Correction of design deficiencies

        (1) Modify operation
        (2) Institute construction to eliminate deficiencies

    c. Correction of management/administration deficiencies

        (1) Obtain owner support
            (a) financial
            (b) administrative/management
        (2) Institute proper in-plant administrative/management programs

    d. Correct maintenance deficiencies

KEY POINTS & INSTRUCTOR GUIDE

Seek class input and discussion as the conclusions are discussed.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
(1) Restore all equipment to working order (2) Institute preventive maintenance program	
4. Correction of one set of factors limiting performance frequently reveals other factors limiting performance.	
5. Long-term contact with plant personnel may be required.	
a. Intensive in-plant evaluation	
b. Intensive in-plant technical assistance	
c. Less intensive long-term follow-up	
6. Every plant is unique and the corrective action program must be tailored to each plant individually.	
D. Discussion	
Use any remaining time for class discussion of the survey project results. Encourage class to relate survey findings to their own experience.	

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 1: Overview

Lesson 3: Significance of Plant O & M

Trainee Notebook Contents

Summary of Survey of Federally Funded Treatment Facilities T1.3.1

Summary of Operation and Maintenance Factors Limiting Municipal Wastewater Treatment Plant Performance T1.3.3

References T1.3.5

Summary of
Survey of Federally Funded Treatment Facilities

(Done under Section 210 of the Water Pollution Control Act)

1. PLANT PERFORMANCE
   - A. Less than half of secondary facilities are meeting secondary effluent requirements.
   - B. Trickling filter plants have more difficulty meeting requirements than activated sludge plants.
   - C. 4,400 secondary plants may not be in compliance.
2. MARGINAL PLANTS
   - A. 20% of all secondary plants - up to 1,700 nationally, are classified as "marginal performers."
   - B. Marginal performers - do not meet secondary requirements, but
   - C. They can meet secondary requirements without significant investments in new construction, thus
   - D. Some 1,700 plants could meet requirements through improved O & M and minor plant modifications.
3. LABORATORY FACILITIES
   - A. Many plants had inadequate lab facilities, thus
   - B. Many facilities could not provide adequate operational data.
   - C. Testing for process control may be low due to inadequate lab facilities.
   - D. Illinois Survey - With an adequate lab, plant performance can be increased by 20%.
4. OTHER FACTORS
   - A. Plants with good maintenance management programs perform better.
   - B. Attention to routine training, short courses, etc., has been lacking.

T1.3.1

5. SURVEY CONCLUSIONS

A. Improved O & M practices, laboratory facilities and training can lead to *major* levels of plant performance improvements and will enable 20% of all secondary plants to meet existing requirements.

B. Based on EPA experience, direct operational assistance to plant operators can result in significant improvements in effluent quality.

C. Assistance programs exemplified by work of The National Training and Operational Technology Center, EPA Cincinnati, show considerable success in providing control methodologies for activated sludge facilities.

6. SIGNIFICANCE

As a result of EPA Survey and conclusions, troubleshooting O & M problems and O & M technical assistance must be stressed as an important part of the overall cleanup effort for water pollution.

For more information see Gilbert, W.G. (listing in References)

Summary of
Operation and Maintenance Factors Limiting Municipal Wastewater Treatment Plant Performance

1. CAUSES OF POOR PLANT PERFORMANCE

    A. Poor operator skills

    B. Inoperable equipment due to poor maintenance and/or poor design

    C. Inadequate testing

2. FACTORS LIMITING PERFORMANCE

    A. Poor application of control concepts and testing to process control by operators

    B. Lack of understanding of wastewater treatment principles by operators

    C. Improper technical guidance from design consultants, regulatory agency personnel, operator trainers, etc.

    D. Inadequate process control testing

    E. Limited process flexibility or controllability

    F. Insufficient solids handling capacity

    G. Improper design

3. NEEDS

    A. Better trained operators

    B. Better trained technical assistance

    C. Design and construction to include:

        (1) Feedback from operations

        (2) Better design criteria

        (3) Better regulations and guidelines

T1.3.3

5. CONCLUSIONS

A. Many factors limit performance at any given treatment plant. All factors which limit performance must be eliminated if the plant is to operate at optimal efficiency.

B. A comprehensive corrective action program must be pursued. The corrective action program must be tailored to the needs of each facility. Elements of a comprehensive corrective action program include: defining the best control strategy, upgrading opeator skills, correcting design deficiencies, correcting maintenance deficiencies, identifying and correcting management/administrative deficiencies.

For more information see Hegg, Bob A. (listing in References)

REFERENCES

1. Azan, K.M, and Boyko, B.I., "Identification of Problem Areas in Water Pollution Control Plants," Research Report No. 15, Ontario Ministry of the Environment, 1973.

2. Evans, Francis L. III, "Summary of National Operational and Maintenance Cause and Effect Survey," *Technology Transfer*, Environmental Protection Agency, Cincinnati, Ohio, July, 1979.

3. Gilbert, W.G., "Relation of Operation and Maintenance to Treatment Plant Efficiency," *Journal Water Pollution Control Federation, 48*, July, 1976, pp. 1822-1833.

4. Hegg, Bob A., Rakness, Kerwin L. and Schultz, James R., "Evaluation of Operation and Maintenance Factors Limiting Municipal Wastewater Treatment Plant Performance," *Journal Water Pollution Control Federation, 50*, March, 1978, Part I, pp. 419-416.

5. Hill, W.R., Regan, T.M., and Zickefoose, C.S., "Operation and Maintenance of Water Pollution Control Facilities: A WPCF White Paper," *Journal Water Pollution Control Federation, 51*, May, 1979, pp. 899-906.

6. The Federal Water Pollution Control Act (PL 92-500) as amended by the Clean Water Act of 1977 (PL 95-217).

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 1: Overview

Lesson 4: Evaluating Treatment Plant Operations - A Board Game

Lesson 4 of 4 lessons Recommended Time: 90 minutes

Purpose: This lesson provides the trainee an introduction to problems typical of those to be presented in the course and requires the trainees to analyze and solve these problems in work groups by playing a board game. The game playing activity forces discussion and interaction between work group members and establishes an openness of communication within the work group. The game playing exercise completes the introduction to the course.

Trainee Entry Level Behavior: The trainee will have completed Unit 1, Lesson 3 before beginning Unit 1, Lesson 4.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. Describe O & M problems typical of those to be developed in the course and recognize that management, administration and people related problems as well as technical problems will be presented in the course.

2. Recognize that there is no unique best solution to any given problem and that there are several acceptable alternative solutions which must be considered when troubleshooting a treatment facility.

3. Interact with others and work as a team to evaluate the potential effectiveness of several alternative solutions, to place the alternatives in priority order and to select a preferred solution from the options available to solve a problem.

Instructional Approach: Simulation with trainee discussion in a team played game.

Lesson Schedule: The 90 minutes allocated to this lesson should be scheduled as follows:

TIME	ACTIVITY
30 minutes before lesson begins	Set Up Game Tables and Boards
0 - 5 minutes	Introduce Game, Its Purposes and How to Play
5 - 15 minutes	Trainees Read Instructions and Scenario
15 - 20 minutes	Distribute Solution Cards
20 - 80 minutes	Trainees Play Game
80 - 90 minutes	Tally Scores and Discuss Game

Trainee Materials Used in Lesson: None

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 1, Lesson 4, pages 1.4.1 - 1.4.13

2. One game set for each group of four trainees. Each game set contains:

   a. One game board
   b. One pair of dice
   c. Four playing pieces
   d. Twenty (20) problem cards in two sets of 10 per set
      (1) Set A: Problem card numbers 1,3,5,7,9,11,13,15,17,19
      (2) Set B: Problem card numbers 2,4,6,8,10,12,14,16,18,20
   e. Sixty (60) solution cards
   f. "Plant Problem" game instructions (4 copies)
   g. Scenario of Board Game (4 copies)
   h. One score sheet

3. One pencil or pen at each playing table

4. (Optional) Small prizes (gag gifts) for winning and losing teams.

Instructor Materials Recommended for Development: The instructor may develop additional problem statements and solution options to tailor the game to course specific needs.

Additional Instructor References: None

Classroom Set-up:

Preferred: A separate room adjacent to or near the main classroom. The room should be set with card tables and seating for four persons at each table. A normal hotel set-up for a bridge or other card party is needed. One table for each group of four trainees is required. Each table should have one complete set of game materials and a pencil or pen. Each table should be numbered and labeled to help trainees locate their work groups.

Acceptable: The main classroom set as described for Unit 1, Lesson 1 may be used to play the game. If this set-up is used, the Course Director should pre-assemble the game sets and package each game set in a large manila envelope to facilitate distribution of game materials to the trainee work groups.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Preparations for Game (15-30 min. before lesson begins) The following preparations should be made by the instructor prior to having the class play the board game.	Guide: All game preparations must be completed prior to the start of the lesson subdivision.
A. Set up card tables in area where game is to be played.	
B. Set tables with game boards and all game materials *except solution cards* which are to be distributed later.	Note: Check to make sure game sets are complete well in advance of the course.
C. Problem cards are to be placed, face down, in numerical order, with the pack of problem cards rubber-banded. Only ten (10) problem cards should be used at each table. Set A (odd numbered problems) or Set B (even numbered problems) should be used.	Note: Only Set A (odd numbered problems) or Set B (even numbered problems) should be used in numerical sequence since the problems are sequenced to follow the course. Problem cards must be folded and sealed. When properly folded, the problem statement will appear on the outside of the card and the solution will be concealed inside the card.
D. Groups of four trainees each should be pre-selected from course roster by the Course Director. Trainees should be grouped so that members of the same group do not know each other prior to the course. If the trainees in the course have varied backgrounds, groups should be mixed so that the players in each group represent the various backgrounds, i.e., MIX-IT-UP!	Note: The composition of the groups should be announced at the completion of Lesson 3 if groups were not formed earlier as described in Unit 1, Lesson 1. Groups should be kept intact for the rest of the course.
II. Instructions and Initiation of Play (20 min.)	
A. Introduce the Game (5 minutes)	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
1. Review purposes of the game with the class.	Guide: These three points are essential to the success of the game. The major purposes of the game are to introduce the course and to promote team work.
2. Make it clear to the class that trainees work in *groups*. Each group *competes* against all other groups. Individuals do not compete with one another.	
3. State that in playing the game, the objective of each group is to successfully troubleshoot treatment plant problems.	
B. Instructions (10 min.)	Refer to "Plant Problems-Game Instructions," *Instructor Notebook*, page 1.4.9.
1. Have trainees read game instructions.	
2. Review principal game instructions with trainees. Answer any questions with regard to how game is played.	
3. Scenario: Have trainees read the Scenario along with instructor who reads Scenario out loud.	Refer to "Scenario of Board Game," *Instructor Notebook*, page 1.4.12.
4. Announce that all solutions are judged in the *context* of the Scenario.	
C. Initiation of Play (5 min.)	
1. Distribute one pack of Solution Cards to each table.	
2. Players shuffle Solution Cards.	
3. Each player is dealt 12 Solution Cards, which he places face upward (text showing) in front of him on the table, arranged so that he can read his cards easily. The remaining 12 Solution Cards are placed face downward in a pack in the appropriate square on the board.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
4. Players should look at and learn the contents of each of the 12 Solution Cards in front of them.	Key Point: The Solution Cards dealt to the player represent his/her total knowledge of wastewater treatment plant troubleshooting. The player must make his/her recommendations from the knowledge which he/she has and must then defend his/her recommendations.
5. Instructor should point out that there is always a chance that a group *will not* have the right solution to a problem face up, inasmuch as 1/5 of all solution cards are face down in the pack.	Key Point: In the "real world" the right solution is not always available - thus the element of chance.
6. Players should roll dice and begin.	
III. Play (60 minutes)	Instructors should remain present to observe play and answer questions.
A. At the start of play, instructor should provide guidance to see that each group understands the rules.	
B. Instructor should make sure that groups *discuss* their problem solutions between them. This dicussion is very important and should be encouraged.	Key Point: Make groups discuss alternative solutions before making the selection. Remember one purpose is to promote interaction and to develop a spirit for team work. Oral communication skills are practiced as trainers defend their recommendations.
C. Questions and comments that come up during play.	
1. Two "doubles" in a row. If a group lands on the "double" square two plays in a row, the next problem *does not count* four times the value. Instead, the next two problems *each* count twice the value.	

LESSON OUTLINE

2. What is a "stuck" digester? This expression is not universally known. It is a digester that is not operating, not generating gas. It does not mean that the cover is stuck.

3. Groups occasionally complain that a "correct" answer is incorrect, or vice-versa. Instructor should comment that the course developers judged these answers correct in relation to the Scenario, and that some answers are arguable. However, *no* adjustment in the scores should be allowed.

4. Groups occasionally feel cheated because none of the players had a correct solution card in front of them. Explain that this is due to the element of chance, and that all groups have the same odds. However, this parallels reality, in that most troubleshooters, with their own background and training, rarely have all of the answers available to them.

D. After 40 minutes, encourage all groups to complete their 10 problems in the remaining 20 minutes.

IV. Conclusion of Play (10 min.)

A. Call play to a halt.

B. Have each group add up the number of checks (✓).

C. Any group with 5 or more X's may not win.

D. Have each group announce its score.

E. Award prizes to group with highest and lowest scores.

KEY POINTS & INSTRUCTOR GUIDE

Key point: Operators have their own jargon. Troubleshooters must learn to speak the operators' language.

Note to Course Director: Awarding of prizes is optional. Gag

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	prizes are preferred if prizes are awarded.
A score of 15 ✓'s is typical for the game. The highest score obtained after fourteen presentations was 24.	
	In the time remaining, seek class reaction to the game and comments.

"PLANT PROBLEM" - GAME INSTRUCTIONS

EQUIPMENT:

Each playing table of four players uses one (1) playing board, four (4) different board peices, ten (10) Problem Cards, sixty (60) Solution Cards, four (4) Scenario Sheets, one (1) score sheet, four (4) sets of instructions, and one (1) pair of dice.

SET-UP:

1. A stack of ten Problem Cards is placed face downward in the appropriate square in the center of the board. (Note: each table's set of ten Problem Cards is drawn from a total set of twenty created for the game.)

2. The deck of Solution Cards is shuffled, and each player is dealt 12 Solution Cards, which he/she places face upward (text showing) in front of him/her on the table, arranged so that he/she can read his/her cards easily. The remaining twelve Solution Cards are placed face downward in the appropriate square at the center of the board.

3. Players each select the board piece they wish to use. All four board pieces are then placed in the "Start" square on the board.

PLAY:

1. The Scenario Sheet is read aloud to all tables by the instructor, to provide a background against which the game is to be played.

2. Players each roll the dice once. Player at each table with the highest roll goes first, followed by player to his/her left. Play rotates clockwise around the board.

3. Each player rolls dice and moves his/her board piece the number of squares indicated by the dice. Player follows instructions on the board square upon which his/her piece lands.

4. When instructed to draw a Solution Card, player takes a card from the top of the Solution Card deck on the board and places it face upward on the table among those already in front of him/her.

5. When instructed to discard a Solution Card, player selects the one Solution Card among those he/she holds that he/she feels he/she is least likely to need and buries that card face downward in the middle of the Solution Card deck on the board.

6. When a player lands on a "problem" square, he/she draws a Problem Card from the top of the deck on the board, turns it over, and records the number of the problem (found at the end of the problem description) under the "Problem Number" column on his/her table's score sheet. He/She then reads the problem aloud to the other players at the table, but does not yet break the seal on the edge of the Problem Card.

7. Each player now selects one Solution Card among those which he/she holds - the one he/she feels is best for the problem at hand. He/she reads this Solution Card aloud to the other players at the table and explains his/her choice.

8. When all four players have picked the Solution Card they wish to offer in response to the problem, players may engage briefly in group discussion-to consider the adequacy of each of the four alternative Solution Cards under consideration.

9. Player who drew the Problem Card must now select the one Solution Card - his/hers or one of those offered by one of the other players - which he/she feels represents the best initial approach to the problem. He/she records the number of this Solution Card (found at the end of the solution description) on the table's score sheet, under the "Solution Number" column.

10. Player now breaks the seal on the side of the Problem Card, opens the card, and tells the other players at the table whether the solution he/she chose is considered "Best", "Acceptable", "Worst", or none of these, for the particular problem.

SCORING:

1. If the Solution Card he/she chose is indicated on the inside of the Problem Card to be "Best", player enters a double check (✓✓) on the score sheet under the "Outcome" column. If "Acceptable", he/she enters one check mark (✓), and if "Worst", he/she enters an "X". If Solution Card he/she chose is not any of these, he/she leaves the "Outcome" column blank.

2. If any player has landed on the "Next problem counts double" square since the last problem was drawn, double checks become four checks, single checks become double checks, and "X's" become "XX's" for the problem at hand.

3. When finished with a Problem Card, the player closes the card and places it face upward at the bottom of the Problem Card deck on the board. (Card is resealed after the game is over.)

4. Play continues until table has used all ten problem cards on their board and attempted to solve each of these following the procedure described. Table with greatest number of check marks on their score sheet at game's end, wins. (Exception: any table receiving five (5) or more X's may not win, regardless of the number of check marks that table receives during the game.)

SCENARIO OF BOARD GAME

The Board of Trustees of Independence County, located in the urban-industrial center of your state, has recently voted to establish a consolidated, county-wide sanitary district which will construct, own, and operate all municipal sewerage facilities in the county. The District will assume jurisdiction over all existing treatment plants in the county, including those in the less populated, rural areas, and those serving private subdivisions. In all, when it comes into existence, the District will acquire the following facilities:

a. Three (3) activated sludge (secondary treatment) plants, with industrial waste loads. Capacity: 2.5 to 60 mgd.

b. Five (5) trickling filtration (secondary treatment) plants, with some industrial waste loads. Capacity: 0.75 to 9.0 mgd.

c. Twelve (12) aerated lagoons. Capacity: 0.10 to 0.70 mgd.

d. One (1) primary treatment plant, 5 mgd.

e. Two (2) spray irrigation facilities, handling a total load of 0.25 mgd, following secondary treatment.

f. One (1) advanced waste treatment plant, 0.2 mgd, which consists of chemical clarification, sand filtration and activated carbon adsorption following biological nitrification.

g. A variety of sludge handling facilities, including anaerobic digestion, sludge drying beds, vacuum filtration, incineration and landfill.

h. Twenty-five (25) "package" treatment plants serving residential subdivisions.

The Executive Director, brought in from another State for the job, has heard rumors of faulty and inefficient operations at many of the facilities he is about to control and has seen some evidence to this effect in the operating records of the District's plants. Because of his concern, he has requested an outside team of top field people to evaluate and troubleshoot the plants in Independence County.

You are a specialist in treatment operations. You have been working on other projects and are unfamiliar with the plants, the problems and the personnel in the new Independence County Sanitary District. You will head a team of three (3) other operations specialists and will be assigned to assist the District in improving treatment plant operations throughout the county. You will rely on the judgment of the members of your team, and of course, on the plant operators: but you have been given the final authority to determine what, if any, changes need to be made at the plants which you are about to evaluate. All plant superintendents and operators in the District have been notified that your evaluation team will visit their plants to assist them in upgrading performance. Your recommendations are to go directly to the new Executive Director who will be responsible for implementing your recommendations.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 2: Elements of Troubleshooting

Unit 2 of 15 Units   Recommended Time: 1 1/2 hours

Lessons in Unit: 2

Instructor Overview of the Unit

Rationale for Unit: Because many factors may affect the performance of wastewater treatment facilities, it is essential that the troubleshooter approach a technical assistance project in a *systematic and orderly* way. The Unit develops a systematic procedure for analyzing wastewater treatment facilities to identify problems, assign causes to the problems and develop alternative solutions and implement corrective action programs. The systematic procedure, called the *Process of Troubleshooting*, is applied to wastewater treatment facility evaluation and troubleshooting.

Because the troubleshooter must obtain information from and implement his/her recommendations through the plant operating staff, the unit stresses the importance of troubleshooter attitudes and behavior in successful troubleshooting and prepares the trainee to recognize and use good troubleshooter behavior in technical assistance projects.

Trainee Entry Level Behavior: Unit 2, *per se*, requires no specific knowledge of wastewater treatment technology or operations because it focuses on an approach to problem solving which is applicable to many different situations.

In the context of the course or other courses based on the *Troubleshooting O & M Problems in Wastewater Treatment Facilities* training materials, the trainee should have completed Unit 1 or its equivalent.

Entry level behavior for the course is as specified in Unit 1. Therefore it is suggested that, as a prerequisite to Unit 2, the trainee be able to:

1. Given a photograph, drawing, schematic or verbal description of wastewater treatment equipment or processes, the trainee will be able to:

    a. identify and name the treatment equipment or process unit;

   b. State the purpose and function of each piece of equipment and each unit in the process;

   c. Identify, point out and name the component parts of the equipment or process;

   d. Describe how each component works and why it is important to the performance of the overall treatment system;

   e. List the typical operating ranges of control parameters for equipment, unit processes and their component parts; and

   f. Describe the normal or routine operation and maintenance procedures for equipment, unit processes and their component parts.

2. Given essential design and operating data for equipment, unit processes or treatment systems:

   a. State whether or not the equipment, unit process or treatment system is performing normally; and

   b. State whether or not the equipment, unit process or treatment system is performing satisfactorily.

3. Given access to wastewater treatment equipment, unit processes and systems which are operating well, perform normal or routine process control, operations and maintenance tasks correctly.

Trainee Learning Objectives: After completing Unit 2, *Elements of Troubleshooting*, the trainee will be able to:

1. From memory, define "Troubleshooting."

2. From memory, describe and contrast the roles of the "operator" and the "troubleshooter" in a technical assistance project.

3. From memory, list at least five characteristics of a good troubleshooter and explain the importance of each in successful troubleshooting.

4. From memory, list the five major steps in the *Process of Troubleshooting*, describe the activities which are included in each step and explain the significance of each activity to effective troubleshooting.

5. Using the flow charts, pages T2.2.9 and T2.2.10 in the *Trainee Notebook*, explain how the *Process of Troubleshooting* is applied to performance evaluation and problem solving at a wastewater treatment facility.

6. From memory, list at least five sources of technical information about a particular treatment facility and at least five sources of technical information about treatment plant operations which might be used by the troubleshooter.

7. From memory, list at least four indicators of effective troubleshooting and describe how these factors may be used to evaluate troubleshooting project success.

Sequencing and Pre-Course Preparation for the Unit: Unit 2, *Elements of Troubleshooting*, is presented as two lessons.

Lesson 1: Attitudes and Human Behavior in Troubleshooting

Recommended Time: 45 minutes

Purpose: Defines "troubleshooting," discusses the roles and responsibilities of the "operator" and the "troubleshooter" in technical assistance projects, establishes the importance of interpersonal skills in troubleshooting and identifies good and bad characteristics of troubleshooter behavior.

Training Facilities:

a. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees in groups of four;

b. Instructor table with lectern;

c. Large projection screen (6' x 6' minimum) and chalkboard in front of room and readily visible to all trainees;

d. Easel with pad;

e. 35mm carousel projector with remote control changer at instructor table;

f. At least four empty carousel trays;

g. Overhead projector

h. Chalk, felt-tip makers and erasers;

i. Six to eight chairs randomly spaced at back and sides of room for visitors.

Pre-Course Preparation:

a. Reproduce and make available in the *Trainee Notebook*, pages T2.1.1-T2.1.2.

b. Provide each trainee a copy of the *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*.

c. Identify and brief three trainees to role play the parts of troubleshooters Joe and Tom and plant operator Bob. Provide dialogue scripts to "actors" before lesson begins so that they have time to review them before-hand. Two copies of each script are needed.

Instructional Approach: Illustrated lecture, trainee role playing and class discussion.

Lesson 2: The Process of Troubleshooting

Recommended Time: 45 minutes

Purpose: Presents systematic step by step procedure, the *Process of Troubleshooting*, for planning, organizing and conducting a troubleshooting (technical assistance) project and describes how the *Process of Troubleshooting* is applied to wastewater treatment facilities.

Training Facilities: Same as Unit 2, Lesson 1.

Pre-Course Preparation: Reproduce and make available in the *Trainee Notebook*, pages T2.2.1-T2.2.12.

Instructional Approach: Illustrated lecture with class discussion.

Presentation Options for the Course Director: The 90 minute Unit of Instruction on *Elements of Troubleshooting* sets the stage for the entire course. Principles introduced in this Unit are expanded upon and reinforced in subsequent lessons. Therefore, this Unit is absolutely essential to the course. It cannot be eliminated and should not be reduced in length of time or in scope.

If this Unit were to be eliminated, some of the basic points of the course would be lost. Therefore, there are few options available for modification.

One option considered by the course developers to be potentially worthwhile is to use additional faculty in the unit who are experienced troubleshooters and who can reinforce the approach being presented. Operators, plant superintendents, municipal or sewer district officials, state or EPA field and O & M personnel or operations consultants could be called on to illustrate the unit by relating their experiences in troubleshooting.

Another option is to modify the unit to introduce employer specific requirements in troubleshooting projects such as check lists, forms and reporting formats or procedures. The unit materials could then be related to specific internal procedures. Such modifications would likely require that the Unit 2, Lesson 2 time requirement be increased.

Summary of Unit of Instruction 2: *Elements of Troubleshooting*

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Attitudes and Human Behavior in Troubleshooting 45 minutes	1. Define troubleshooting. 2. Relate human behavior aspects of troubleshooting to the trainees' jobs. 3. Discuss the role of troubleshooters in relation to plant operators. 4. Differentiate between human and technical skills. 5. Compare positive and negative types of troubleshooter behavior.	1. Human attitudes and behavior in troubleshooting. 2. Analysis of type of troubleshooter behavior. 3. Good characteristics of troubleshooter behavior.	1. Use outline and slides, maximize class discussion. 2. Present two troubleshooting dialogues. 3. Analyze two troubleshooting dialogues with class discussion. 4. Discuss troubleshooter behavior, using chalkboard to record input.	1. Slide series and key. 2. Troubleshooting dialogues No. 1 and No. 2, scripts. 3. *Trainee Notebook* pages T2.1.1 - T2.1.2.
2. The Process of Troubleshooting 45 minutes	1. List the basic elements of troubleshooting. 2. Use the chart, the *Process of Troubleshooting*.	1. The importance of a systematic approach. 2. The basic elements of troubleshooting.	1. Use outline and slide key. 2. Maximize student discussion and involvement.	1. Slide series and key. 2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities.*

Summary of Unit of Instruction 2: *Elements of Troubleshooting* (continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
	3. Locate and identify useful information.	3. Troubleshooting Chart steps and elements in the *Process of Troubleshooting*.		3. Inspection checklist, *Trainee Notebook*, pages T2.2.1 - T2.2.7.
	4. Approach plant problems by formulating alternative solutions.	4. The importance of alternatives.		4. Charts, the *Process of Troubleshooting*, *Trainee Notebook*, page T2.2.8 - T2.2.10.
	5. List criteria for effective technical assistance.	5. Importance of final troubleshooting steps.		5. *Trainee Notebook*, pages T2.2.11 - T2.2.12.
		6. Criteria for effective technical assistance.		

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 2: Elements of Troubleshooting

Lesson 1: Attitudes and Human Behavior in Troubleshooting

Lesson 1 of 2 Recommended Time: 45 minutes

Purpose: This lesson defines "troubleshooting," discusses the roles and responsibilities of the operator and the troubleshooter in technical assistance projects, differentiates between interpersonal and technical skills in troubleshooting, identifies and contrasts characteristics of good and bad troubleshooter behavior and discusses potential goals of troubleshooting (technical assistance) projects. The lesson stresses the importance of attitudes and behavior in dealing with plant operating personnel during an assistance project.

Trainee Entry Level Behavior: As specified in the Instructor Overview of the Unit, page 2.1.

Trainee Learning Objectives: At the conclusion of this lesson the trainee will be able to:

1. From memory, define "troubleshooting."
2. From memory, describe and contrast the roles of the "operator" and the "troubleshooter" in a technical assistance project.
3. Given a listing of skill descriptions, differentiate between interpersonal and technical skills and explain the importance of each skill in effective troubleshooting.
4. From memory, list and describe at least five examples of objectives or goals for a technical assistance project.
5. From memory, compare good and bad troubleshooting behavior by citing at least five characteristics of each behavior and explain why troubleshooter behavior is important to troubleshooting project success.

Instructional Approach: Illustrated lecture, trainee role playing and class discussion. The instructor should follow the lesson plan provided.

Lesson Schedule: The 45 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
Before Lesson Begins	Brief Three Trainees for Role Playing
0 - 5 minutes	Purpose and Objectives Lesson
5 - 15 minutes	The Nature of Troubleshooting
15 - 35 minutes	Troubleshooting Behavior - Illustrative Dialogue
35 - 45 minutes	Characteristics of Good Troubleshooter Behavior

Trainee Materials Used in Lesson: *Trainee Notebook*, pages T2.1.1 - T2.1.2.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 2, Lesson 1, pages 2.1.1 - 2.1.13
2. Slides 179.2/2.1.1 - 179.2/2.1.9.
3. Troubleshooting Dialogue No. 1, script, pages 2.1.14 - 2.1.16 (2 copies).
4. Troubleshooting Dialogue No. 2, script, pages 2.1.17 - 2.1.19 (2 copies).

Instructor Materials Recommended for Development: None suggested.

Additional Instructor References: None suggested.

Classroom Set-Up: Large classroom (40' x 40') set with table and chair seating in "herring bone" or "U" shape with all seats facing the front of the room. Trainees should be seated with their pre-assigned work group.

An instructor's table with lectern, a large projection screen (6' x 6' minimum), a chalkboard and an easel should be placed at the top of the "herring bone" so that they can be easily seen by all trainees.

A 35mm carousel type slide projector with remote controls extending to the instructor's table and four empty slide trays should be in the room. An overhead projector with several sheets of blank transparency film should be available.

Supplies, such as chalk, marking pens, transparency film marking pens, erasers, a pointer, etc. should be located at the instructor's table.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Prepare for Troubleshooting Dialogues (before lesson begins)	Scripts located at pages 2.1.14 - 2.1.19.
A. Identify three trainees to participate in role playing. "Actors" to play roles of troubleshooters, Joe and Tom, and plant operator Bob are needed.	
B. Assign roles and provide copies of the script to selected trainees.	
C. Brief trainees that purpose of role playing is to illustrate extremes in troubleshooter behavior.	
D. Inform "actors" that they may ad-lib as long as they do not change the tone of the operator/troubleshooter interaction, i.e., stay in character.	
E. Suggest that they review the script before they "go on" about mid-way in the lesson.	
II. Purpose and Objectives of Lesson (5 min.)	Use Slide 179.2/2.1.1 Slide 179.2/2.1.1 is a blank or black slide used as a convenience to darken the screen.
A. Definition of Troubleshooting	Use Slide 179.2/2.1.2
1. Emphasize and discuss following points: a. Problem solving at b. an existing facility which c. is operating but d. has operational problems which e. cause poor performance	Slide 179.2/2.1.2 reads: "Definition of Troubleshooting Troubleshooting is the practice of problem solving applied to an existing facility in use and experiencing operational problems which affect its performance."
2. Definition implies that plant could perform better if O & M practices were improved.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. Troubleshooting, sometimes called technical assistance, is the procedure used to identify and correct these operational problems through:	
a. Improved process control practices or	
b. Improved maintenance procedures or	
c. Improved management practices or	
d. Minor facility modification short of major construction or	
e. Any combination of the above.	
B. Troubleshooting technical assistance is being stressed as an effective procedure to improve the performance of treatment facilities. Numerous examples demonstrate the effectiveness of in-plant technical assistance programs.	Refer to Unit 1: *Overview*, Lesson 3: Significance of O & M
C. Purpose and objectives of this Unit of Instruction:	Use Slide 179.2/2.1.3
1. Highlight the essential elements of troubleshooting	Slide 179.2/2.1.3 is a blank or black slide used to darken the screen.
a. Stress importance of troubleshooter attitudes and behavior to establishing effective communication.	
b. Identify skills, both technical and non-technical, needed in troubleshooting.	
c. Establish the role and responsibility of the troubleshooter relative to those of the operator.	
d. Illustrate good and bad characteristics of troubleshooter behavior.	

LESSON OUTLINE

2. Develop a systematic procedure for approaching a troubleshooting problem.

3. Apply this process of troubleshooting to wastewater treatment facilities.

III. The Nature of Troubleshooting (10 min.)

A. Troubleshooting is a process - not just a simple problem-solution activity.

1. May involve several plant visits over an extended time period.

   a. Initial evaluation

   b. Problem identification and solution options

   c. Follow-up evaluations

2. Troubleshooting may not lead to a unique right answer but to several effective solutions. The process of troubleshooting provides an approach to problem solving which aids in identifying problems, potential causes and several alternative solutions with final selection of preferred solutions.

3. The role of the troubleshooter is indirect; he is there to assist the operator.

   a. The operator is responsible for running the plant.

   b. The troubleshooter is there to help the operator not to take his/her place.

   c. The troubleshooter works through the operator.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/2.1.4

Slide 179.2/2.1.4 reads:

"Solving Treatment Plant Problems

Operator	Troubleshooter
Direct Control Over Plant Operations	Indirect Role Uses Experience to Assist"

LESSON OUTLINE

4. Because the troubleshooter's role is indirect he must rely on both

   a. Human (interpersonal) skills to affect the operator.

   b. Technical skills to affect the plant.

   c. Weakness in either human or technical skills can affect project outcome.

   d. Have class discuss points on Slide 179.2/2.1.5 and identify other skills that are important to troubleshooter.

B. Components for Success in Troubleshooting

   1. Knowledge of

      a. The physical facility.

      b. The people running the facility.

      c. The situation.

      d. Specific troubleshooting project goals.

   2. Troubleshooter must do his/her "homework" before beginning a technical assistance project.

      a. Plant organization - relationship of personnel

         (1) Who's in charge?
         (2) Who has responsibility?
         (3) Who does what? When?
         (4) Who knows what's going on?

      b. External Community Conditions

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/2.1.5

Slide 179.2/2.2.5 reads:

"Troubleshooter Relationships

Operator	Plant
Human Skills:	Technical Skills:
Attitude	Experience
Judgment	Process Control
Sincerity	Logic
Friendliness	Technical 'know how'"

List additional skills identified by class on chalkboard.

Use Slide 179.2/2.1.6

Slide 179.2/2.1.6 reads:

"For Each Plant - Troubleshooter Must Understand

- * Plant Organization - Relationship of Personnel
- * External Community Conditions
- * Past Plant Performance
- * Plant Operations and Processes
- * Environmental and Regulatory Requirements - EPA, State, Local"

(1) Who has authority over the treatment plant?
(2) What is upper management and community attitude toward the plant?
(3) What are local priorities?

c. Past plant performance

(1) New problem? Old problem?
(2) Trends?
(3) Do on-set of problems correlate with other events such as personnel changes, new industry in town, etc.?

d. Plant operations and processes

(1) What is in the plant?
(2) How is it operated?

e. Environmental and regulatory requirements - EPA, state, local

(1) Enforcement?

    (a) Underway?
    (b) Potential?

(2) Any special requirements or constraints?

3. Troubleshooting Goals

a. Review items on Slide 179.2/2.1.7

b. Ask class to identify other possible goals for technical assistance projects.

c. Stress that goals must be defined before the project begins. Project must have direction. Troubleshooting is goal oriented; it is

Use Slide 179.2/2.1.7

Slide 179.2/2.1.7 reads:

"Troubleshooting Goals
- Repairing Breakdown or Immediate Problem
- Preventing Recurrence of Problem
- Improving Long-Run O & M
- Upgrading Overall Plant Efficiency"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
not haphazard diddling with the process. Without direction the project will flounder.	
C. Troubleshooter Roles	Use Slide 179.2/2.1.8
1. Use Slide 179.2/2.1.8 to touch on variety of things that a troubleshooter must be able to do:	Slide 179.2/2.1.8 reads: "Troubleshooters Are
a. Investigate b. Solve problems c. Devise new approaches for dealing with design/mechanical shortcomings d. Advise operators e. Assist operators	* Investigators * Problem Solvers * Mechanics * Psychologists * Assistants"
2. Stress that troubleshooter role is indirect because the troubleshooter works through the operator.	
3. Because the role is indirect, the troubleshooter's skill in interpersonal relationships is equally as important as his/her technical skill.	
	Advance to Slide 179.2/2.1.9 Slide 179.2/2.1.9 is a blank used to blacken the screen. Turn Up Lights
IV. Troubleshooter Behavior Illustrative Dialogues (20 min.)	Preparations given on page 2.1.3 should be completed before beginning this action. Scripts for dialogues are located at pages 2.1.14 - 2.1.19.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
A. Present Dialogue No. 1 to the Class (10 min.)	
1. Call "Joe" and "Bob" to the front of the room with their scripts.	
2. Read the following opening statement on the "situation" to the class	Instructor reads situation to class.
Joe is an engineer in the operations branch. He has two years post-graduate experience and has had graduate level courses in Sanitary Engineering.	
Joe is assigned by his office to inspect and evaluate a 10 mgd activated sludge plant with a normal domestic waste flow of 6 mgd. The plant has an excellent lab. The plant effluent has not been meeting standards, and has been turbid. Septic odors are evident in proximity to the aeration basins.	
Upon entering the plant, Joe meets Bob who is the chief operator on the day shift. Before this plant was built, Bob was the operator of a 1.5 mgd trickling filter plant operated by the city. He is 53 years old and has been in wastewater treatment for 22 years. He is a night school graduate of high school and a certified operator. Until this inspection, Joe and Bob have not met before.	
3. Have "Joe" and "Bob" present dialogue No. 1.	
4. Analysis of dialogue No. 1. At the completion of dialogue No. 1, ask the class to comment on characteristics of Joe's behavior that they observed. Some observations about Joe include:	Class discussion should be encouraged by the instructor.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
a. Attitude - he made it sound like he was doing the operator a favor by being there.	
b. Put down the plant - said no one gives a damn about it.	
c. Unfamiliar with operator - probably didn't know he was there for a long time.	
d. "Know-it-all" - didn't want to review the data and the plans.	
e. Not investigative - said all activated sludge plants are alike.	
f. Poor attitude toward operators - blames them for all plant problems.	
g. Threatens strong legal action instead of stressing cooperation.	
h. Does not consider alternatives - "knows it all" sees one and only one right solution to the problem.	
i. Did not follow operator's suggestions.	
j. Tried to impress the operator with his Master's degree.	
5. Following this analysis, ask the class if they've ever met someone like Joe.	
B. Present Dialogue No. 2 to the class (10 min.)	
1. Call "Tom" and "Bob" to the front of the room with their scripts	
2. Read the following opening statement on the "situation" to the class	Instructor reads situation to class.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

Tom is an operations specialist. He has a degree in chemistry and 12 years of experience. His experience includes operation of waste treatment plants.

He is assigned by his office to inspect and evaluate a 10 mgd activated sludge plant with a normal domestic waste flow of 6 mgd. The plant has an excellent lab. The plant effluent has not been meeting standards and has been turbid. Septic odors are evident in proximity to the aeration basins (same plant as before).

Upon entering the plant, Tom meets Bob who is the Chief Operator on the day shift. Before this plant was built, Bob was the operator of a 1.5 mgd trickling filter plant operated by the city. He is 53 years old and has been in wastewater treatment for 22 years. He is a night school graduate of high school and a certified operator. Until this inspection, Tom and Bob have not met before.

3. Have "Tom" and "Bob" present dialogue No. 2

4. Analysis of dialogue No. 2. At the completion of dialogue No. 2, ask the class to comment on characterisitics of Tom's behavior that they observed. Some observations about Tom include:

   a. Shows interest - has wanted to see the plant.

   b. Sympathizes with operator - talks about other plants with problems.

   c. Shows knowledge and appreciation of operator.

Encourage class discussion.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
d. Did his homework - looked at plans and data.	
e. Offers encouragement and assistance to the operator.	
f. Plans to share troubleshooting experience with the operator.	
g. Recognizes the operator's experience.	
h. Is investigative - looks for cause of the problem.	
i. Stresses process control tests.	
j. Will assist operator in setting up process controls.	
k. Takes a personal interest in the operator - develops a good relationship.	
	At the end of the 20 minutes on the dialogues, lead directly into the next section.
V. Characteristics of Good Troubleshooter Behavior (10 min.)	Guide: This section should encourage maximum class participation.
A. Instructions:	
1. Ask one trainee to go to the chalkboard as the recorder.	
2. Ask class to suggest characteristics of "good" troubleshooter behavior, i.e., behavior they feel is beneficial in troubleshooting plant problems.	
3. The instructor can set the stage by asking the trainees to imagine that	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
they are a chief in the Plant Operations Section about to interview new employees to be field staff to provide in-plant assistance. What characteristics would they look for?	
B. Have trainees suggest good troubleshooter characteristics and why. Recorder should record the suggestions on the chalkboard. Have trainees discuss points as they come up. Establish why the characteristic is important to good troubleshooter behavior.	
C. Possible characteristics of Good Troubleshooter Behavior:	Guide: This list should be used as the instructor's reference
1. Thorough and open communication	
2. Ability to listen and understand	
3. Honesty and sincerity	
4. Respect for the operator	
5. Understands his/her own limitations - knows when to get help	Note: This list is by no means complete.
6. Assists operator - works through mutual participation	
7. Judgment and common sense	
8. Interest in the operator's problems	
9. Self-confident	
10. Well prepared with background data	
11. Tactful	
D. Refer trainees to page T2.1.1 in the *Trainee Notebook* which summarizes the key points in this lesson.	

DIALOGUE NO. 1

JOE: HI - I'M JOE SMARTASS. MY BOSS TELLS ME YOU'VE BEEN HAVING PROBLEMS, SO HE SENT ME UP HERE. I REALLY DIDN'T WANT TO COME 'CAUSE I'M FALLING BEHIND IN WRITING MANUALS - BUT HE TOLD ME I HAVE TO TRY TO HELP YOU OUT.

BOB: NICE TO MEET YOU, JOE. I SURE HOPE YOU CAN HELP.

JOE: IT'S NO WONDER THE PLANT IS FOULED UP - I'VE HEARD THEY'VE BEEN HAVING PROBLEMS UP HERE FOR THIRTY YEARS AND THAT NO ONE IN THIS TOWN REALLY GIVES A DAMN ABOUT CLEAN WATER.

BOB: HOW ABOUT A CUP OF COFFEE WHILE WE GO OVER SOME OF THE PLANT RECORDS AND PLANS?

JOE: WELL, THANKS - BUT THERE'S NO NEED TO POUR OVER A LOT OF PLANS AND DATA. THESE ACTIVATED SLUDGE PLANTS ARE ALL ALIKE. THEY'RE NEVER OPERATED THE WAY THEY'RE SUPPOSED TO BE ANYWAY.

LET'S SEE, THIS ONE WAS DESIGNED BY SHOVEL & SNOW, WASN'T IT? THEY DO A PRETTY GOOD JOB - I ONCE ATTENDED AN ADVANCED TREATMENT SYMPOSIUM GIVEN BY THEIR ENGINEERS. TROUBLE IS THE OPERATORS AROUND JUST AREN'T SMART ENOUGH TO RUN THESE PLANTS THE WAY GOOD OLD S & S DESIGNS THEM.

Dialogue #1

BOB: Well...

JOE: We don't need to look at the lab data - we know that you haven't been meeting standards - if you don't do something, the state's going to have to take some pretty strong action - those lawyers are just itching to get their hands on a couple of towns like this. You know, with this new law the people running these plants are subject to criminal prosecution. They're going to get tough with some of you yokels.

BOB: Let's take a walk around the plant Joe, there may be a few things you can help on.

JOE: No need for that. Ninety percent of these plant problems are caused by sludge bulking. Why--I've seen three plants like that myself. Hell, even doctors can't tell what's wrong with a patient to 90% accuracy. That's what's so good about being a Sanitary Engineer - you don't need to carry malpractice insurance--you're usually right the first time. Anyway, if you wipe out the bugs they can't sue you.

BOB: Are you sure you know what's going on? What about looking at the influent and the aeration tanks?

DIALOGUE #1

JOE: OH, THEY'RE ALL THE SAME. NOW I'VE GOT THIS TROUBLESHOOTING MANUAL FROM EPA THAT TELLS YOU WHAT TO DO FOR BULKING. JUST FOLLOW THE INSTRUCTIONS ON PAGE 73 AND SEE IF THINGS DON'T GET BETTER IN A FEW DAYS. I'VE GOT TO SPLIT SO I CAN GET TO MY GRADUATE CLASS IN ADVANCED MICROBIOLOGY. BOY, I CAN'T WAIT 'TIL I GET THAT MASTERS DEGREE. THEN I'LL REALLY BE ABLE TO HELP OLD TIMERS LIKE YOU.

-CURTAIN CLOSES-

DIALOGUE NO. 1

JOE: Hi - I'm Joe Smartass. My boss tells me you've been having problems, so he sent me up here. I really did't want to come 'cause I'm falling behind in writing manuals - but he tole me I have to try to help you out.

BOB: Nice to meet you, Joe. I sure hope you can help.

JOE: It's no wonder the plant is fouled up - I've heard they've been having problems up here for thirty years and that no one in this town really gives a damn about clean water.

BOB: How about a cup of coffee while we go over some of the plant records and plans?

JOE: Well, thanks - but there's no need to pour over a lot of plans and data. These activated sludge plants are all alike. They're never operated the way they're supposed to be anyway.

Let's see, this one was designed by Shovel & Snow, wasn't it? They do a pretty good job - I once attended an advanced treatment symposium given by their engineers. Trouble is the operators around just aren't smart enough to run these plants the way good old S & S designs them.

DIALOGUE #1

BOB: WELL...

JOE: WE DON'T NEED TO LOOK AT THE LAB DATA - WE KNOW THAT YOU HAVEN'T BEEN MEETING STANDARDS - IF YOU DON'T DO SOMETHING, THE STATE'S GOING TO HAVE TO TAKE SOME PRETTY STRONG ACTION - THOSE LAWYERS ARE JUST ITCHING TO GET THEIR HANDS ON A COUPLE OF TOWNS LIKE THIS. YOU KNOW, WITH THIS NEW LAW THE PEOPLE RUNNING THESE PLANTS ARE SUBJECT TO CRIMINAL PROSECUTION. THEY'RE GOING TO GET TOUGH WITH SOME OF YOU YOKELS.

BOB: LET'S TAKE A WALK AROUND THE PLANT, JOE, THERE MAY BE A FEW THINGS YOU CAN HELP ON.

JOE: NO NEED FOR THAT. NINETY PERCENT OF THESE PLANT PROBLEMS ARE CAUSED BY SLUDGE BULKING. WHY--I'VE SEEN THREE PLANTS LIKE THAT MYSELF. HELL, EVEN DOCTORS CAN'T TELL WHAT'S WRONG WITH A PATIENT TO 90% ACCURACY. THAT'S WHAT'S SO GOOD ABOUT BEING A SANITARY ENGINEER - YOU DON'T NEED TO CARRY MALPRACTICE INSURANCE - YOU'RE USUALLY RIGHT THE FIRST TIME. ANYWAY, IF YOU WIPE OUT THE BUGS THEY CAN'T SUE YOU.

BOB: ARE YOU SURE YOU KNOW WHAT'S GOING ON? WHAT ABOUT LOOKING AT THE INFLUENT AND THE AERATION TANKS?

DIALOGUE #1

JOE: OH, THEY'RE ALL THE SAME. NOW I'VE GOT THIS TROUBLESHOOTING MANUAL FROM EPA THAT TELLS YOU WHAT TO DO FOR BULKING. JUST FOLLOW THE INSTRUCTIONS ON PAGE 73 AND SEE IF THINGS DON'T GET BETTER IN A FEW DAYS. I'VE GOT TO SPLIT SO I CAN GET TO MY GRADUATE CLASS IN ADVANCED MICROBIOLOGY. BOY, I CAN'T WAIT 'TIL I GET THAT MASTERS DEGREE. THEN I'LL REALLY BE ABLE TO HELP OLD TIMERS LIKE YOU.

-CURTAIN CLOSES-

DIALOGUE NO. 2

TOM: HI - I'M TOM FIXIT. I'VE BEEN HOPING TO GET A CHANCE TO GET UP HERE TO MEET YOU AND TO TAKE A LOOK AT THIS PLANT, BUT UNTIL NOW THEY'VE HAD ME DOIN' OTHER THINGS. I'VE HEARD YOU'VE BEEN HAVIN' SOME PROBLEMS.

BOB: IT'S NICE TO MEET YOU, TOM. I SURE HOPE YOU CAN HELP.

TOM: WELL, OF COURSE YOU'RE NOT THE ONLY ONE HAVING PROBLEMS THESE DAYS. WHAT WITH THE RAINS WE'VE HAD, ALMOST ALL OF THE PLANTS IN THE VALLEY HAVE BEEN OVERLOADED ONE WAY OR ANOTHER. I CAN'T WAIT UNTIL WE GET SOME OF THESE SEWER PROBLEMS FIXED UP SO THAT THESE PLANTS CAN OPERATE THE WAY THEY'RE SUPPOSED TO.

BOB: HOW ABOUT A CUP OF COFFEE WHILE WE GO OVER SOME OF THE PLANT RECORDS AND PLANS?

TOM: WELL THANKS BOB. YOU RAN THAT OLD TRICKLING FILTER PLANT, DIDN'T YA. THAT WAS SOMETHING BACK IN THOSE DAYS. AN OPERATOR HAD TO BE A JACK-OF-ALL TRADES. I REALLY ADMIRE A GUY THAT CAN DO IT ALL.

DIALOGUE #2

BOB: THINGS AIN'T LIKE THEY USED TO BE, BUT I'M TRYING MY BEST WITH THIS NEW PLANT. IT SURE LOOKS PRETTY, BUT SOMETIMES I WONDER ABOUT THE DESIGN. SOMETIMES THIS PLANT JUST DOESN'T DO WHAT ITS CRACKED UP TO DO.

TOM: I KNOW. BEFORE I CAME OVER I TOOK A LOOK AT THE PLANS AND AT SOME OF THE OPERATING DATA YOU SENT OVER. I THINK YOU'RE RIGHT. THIS PLANT COULD SURE USE A LOT MORE FLEXIBILITY WITH THE LOADS VARYING, THE INFILTRATION, THE HEAVY RAINFALL, AND OTHER PROBLEMS THAT YOU'VE HAD. I THINK, THOUGH, LOOKING AT THE PLANS, THAT YOU AND I CAN FIGURE OUT A COUPLE OF WAYS IN WHICH TO GET THIS PLANT RUNNING A LITTLE MORE SMOOTHLY, AND ALSO LETTING IT TAKE CARE OF SOME OF THAT STORMFLOW THAT'S BEEN COMIN' IN HERE.

BOB: I'M GLAD YOU SAID THAT. I'VE BEEN LOOKING FORWARD TO GETTING SOME HELP. I'M GLAD DOWNTOWN FINALLY ASKED SOMEONE TO HELP US OUT.

TOM: AFTER ALL, YOU'RE THE GUY THAT KNOWS THIS PLANT THE BEST. I THINK THAT WITH A LITTLE OF MY EXPERIENCE AND YOUR KNOWLEDGE OF THIS PLANT, WE PROBABLY HAVE ALL WE NEED TO DO THE JOB. WHY DON'T WE GO FOR A WALK AROUND THE PLANT AND YOU CAN SHOW ME SOME OF THE AREAS WHERE YOU'VE BEEN HAVING PROBLEMS AND SOME OF THE THINGS ABOUT THE PLANT THAT WE CAN'T GET OFF THE PLANS. ALSO, WHY DON'T WE BRING YOUR CHEMIST.

DIALOGUE #2

I HEAR HE'S A PRETTY GOOD OLD BOY AND WE CAN PUT HIM TO WORK RUNNING SOME TESTS. BY THE WAY, WHAT PROCESS CONTROL TESTS HAVE YOU BEEN RUNNING?

BOB: I'LL TELL YOU THE TRUTH, WE'VE BEEN SO BUSY RUNNIN' OUR EFFLUENT SAMPLES AND CHECKIN' SOME OF THE INDUSTRIAL WASTES THAT COME INTO THE PLANT, THAT WE HAVEN'T HAD MUCH TIME FOR PROCESS CONTROL TESTS. FURTHERMORE, GEORGE, HE'S THE CHEMIST YOU KNOW, HE'S NOT REAL FAMILIAR WITH THOSE TESTS. HE'S A CHEMIST FROM WAY BACK AND HE DOESN'T REALLY KNOW MUCH ABOUT RUNNIN' A PLANT.

TOM: THEN BEFORE I GO WE'LL TRY TO FIX YOU UP WITH A SCHEDULE OF PROCESS CONTROL TESTS. THEY'RE REALLY NOT HARD TO DO AND WITH THE KIND OF INFORMATION THEY GIVE YOU, YOU'LL BE ABLE TO DO A HECK OF A BETTER JOB RUNNIN' THIS PLANT.

BOB: THAT SOUNDS ALRIGHT TO ME. JUST SO LONG AS I KNOW WHAT'S HAPPENING SO I CAN MAKE SURE THAT I FOLLOW THROUGH AND DO THE THINGS THAT YOU'RE ABLE TO COME UP WITH. WELL, ARE YOU READY FOR A TOUR AROUND THE PLANT?

TOM: IN A FEW MINUTES. HOW ABOUT A SECOND CUP OF COFFEE? I UNDERSTAND YOU HAVE SOME GREAT FISHIN' NOT TOO FAR FROM HERE...YOU'RE GOING TO HAVE TO TELL ME ABOUT IT.

-CURTAIN CLOSES-

DIALOGUE NO. 2

TOM: HI - I'M TOM FIXIT. I'VE BEEN HOPING TO GET A CHANCE TO GET UP HERE TO MEET YOU AND TO TAKE A LOOK AT THIS PLANT, BUT UNTIL NOW THEY'VE HAD ME DOIN' OTHER THINGS. I'VE HEARD YOU'VE BEEN HAVING SOME PROBLEMS.

BOB: IT'S NICE TO MEET YOU, TOM. I SURE HOPE YOU CAN HELP.

TOM: WELL, OF COURSE YOU'RE NOT THE ONLY ONE HAVING PROBLEMS THESE DAYS. WHAT WITH THE RAINS WE'VE HAD, ALMOST ALL OF THE PLANTS IN THE VALLEY HAVE BEEN OVERLOADED ONE WAY OR ANOTHER. I CAN'T WAIT UNTIL WE GET SOME OF THESE SEWER PROBLEMS FIXED UP SO THAT THESE PLANTS CAN OPERATE THE WAY THEY'RE SUPPOSED TO.

BOB: HOW ABOUT A CUP OF COFFEE WHILE WE GO OVER SOME OF THE PLANT RECORDS AND PLANS?

TOM: WELL THANKS BOB. YOU RAN THAT OLD TRICKLING FILTER PLANT, DIDN'T YA. THAT WAS SOMETHING BACK IN THOSE DAYS. AN OPERATOR HAD TO BE A JACK-OF-ALL TRADES. I REALLY ADMIRE A GUY THAT CAN DO IT ALL.

DIALOGUE #2

BOB: THINGS AIN'T LIKE THEY USED TO BE, BUT I'M TRYING MY BEST WITH THIS NEW PLANT. IT SURE LOOKS PRETTY, BUT SOMETIMES I WONDER ABOUT THE DESIGN. SOMETIMES THIS PLANT JUST DOESN'T DO WHAT ITS CRACKED UP TO DO.

TOM: I KNOW. BEFORE I CAME OVER I TOOK A LOOK AT THE PLANS AND AT SOME OF THE OPERATING DATA YOU SENT OVER. I THINK YOU'RE RIGHT. THIS PLANT COULD SURE USE A LOT MORE FLEXIBILITY WITH THE LOADS VARYING, THE INFILTRATION, THE HEAVY RAINFALL, AND OTHER PROBLEMS THAT YOU'VE HAD. I THINK, THOUGH, LOOKING AT THE PLANS, THAT YOU AND I CAN FIGURE OUT A COUPLE OF WAYS IN WHICH TO GET THIS PLANT RUNNING A LITTLE MORE SMOOTHLY, AND ALSO LETTING IT TAKE CARE OF SOME OF THAT STORMFLOW THAT'S BEEN COMIN' IN HERE.

BOB: I'M GLAD YOU SAID THAT. I'VE BEEN LOOKING FORWARD TO GETTING SOME HELP. I'M GLAD DOWNTOWN FINALLY ASKED SOMEONE TO HELP US OUT.

TOM: AFTER ALL, YOU'RE THE GUY THAT KNOWS THIS PLANT THE BEST. I THINK THAT WITH A LITTLE OF MY EXPERIENCE AND YOUR KNOWLEDGE OF THIS PLANT, WE PROBABLY HAVE ALL WE NEED TO DO THE JOB. WHY DON'T WE GO FOR A WALK AROUND THE PLANT AND YOU CAN SHOW ME SOME OF THE AREAS WHERE YOU'VE BEEN HAVING PROBLEMS AND SOME OF THE THINGS ABOUT THE PLANT THAT WE CAN'T GET OFF THE PLANS. ALSO, WHY DON'T WE BRING YOUR CHEMIST.

DIALOGUE #2

I HEAR HE'S A PRETTY GOOD OLD BOY AND WE CAN PUT HIM TO WORK RUNNING SOME TESTS. BY THE WAY, WHAT PROCESS CONTROL TESTS HAVE YOU BEEN RUNNING?

BOB: I'LL TELL YOU THE TRUTH, WE'VE BEEN SO BUSY RUNNIN' OUR EFFLUENT SAMPLES AND CHECKIN' SOME OF THE INDUSTRIAL WASTES THAT COME INTO THE PLANT, THAT WE HAVEN'T HAD MUCH TIME FOR PROCESS CONTROL TESTS. FURTHERMORE, GEORGE, HE'S THE CHEMIST YOU KNOW, HE'S NOT REAL FAMILIAR WITH THOSE TESTS. HE'S A CHEMIST FROM WAY BACK AND HE DOESN'T REALLY KNOW MUCH ABOUT RUNNIN' A PLANT.

TOM: THEN BEFORE I GO WE'LL TRY TO FIX YOU UP WITH A SCHEDULE OF PROCESS CONTROL TESTS. THEY'RE REALLY NOT HARD TO DO AND WITH THE KIND OF INFORMATION THEY GIVE YOU, YOU'LL BE ABLE TO DO A HECK OF A BETTER JOB RUNNIN' THIS PLANT.

BOB: THAT SOUND ALRIGHT TO ME. JUST SO LONG AS I KNOW WHAT'S HAPPENING SO I CAN MAKE SURE THAT I FOLLOW THROUGH AND DO THE THINGS THAT YOU'RE ABLE TO COME UP WITH. WELL, ARE YOU READY FOR A TOUR AROUND THE PLANT?

TOM: IN A FEW MINUTES. HOW ABOUT A SECOND CUP OF COFFEE? I UNDERSTAND YOU HAVE SOME GREAT FISHIN' NOT TOO FAR FROM HERE...YOU'RE GOING TO HAVE TO TELL ME ABOUT IT.

-CURTAIN CLOSES-

TROUBLESHOOTING O & M PROBLEMS IN
WASTEWATER TREATMENT FACILITIES

Unit of Instruction 2: Elements of Troubleshooting

Lesson 1: Attitudes and Human Behavior in Troubleshooting

Trainee Notebook Contents

Notes on Troubleshooting Behavior T2.1.1

NOTES ON TROUBLESHOOTER BEHAVIOR

Definition of Troubleshooting:

Troubleshooting is the practice of problem solving - as applied to an existing facility in use and experiencing operational problems which affect its performance.

Troubleshooting is a Process Which:

1. May require repeated visits over a period of time.
2. Often cannot produce a single "right" answer.
3. Provides an *approach* to solving problems.
4. Requires an indirect role; a troubleshooter's job is to *assist* the operator.
5. Depends on human *and* technical skills.

Troubleshooting Goals Include:

1. Repairing breakdown or immediate problem.
2. Preventing reoccurrence of problem.
3. Improving long-run O & M.
4. Upgrading overall plant efficiency.
5. Training plant operations staff.

Troubleshooters are:

1. Investigators
2. Problem solvers
3. Mechanics

4. Psychologists
5. Assistants

Characteristics of Good Troubleshooter Behavior:

1. Thorough and open communication
2. Ability to listen and understand
3. Honesty and sincerity
4. Respect for the operator
5. Understands his/her limitations and knows when to get help
6. Assists the operator - works through mutual participation
7. Judgment and common sense
8. Interest in the operator's problems
9. Self-confident
10. Well prepared with background data
11. Tactful

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 2: Elements of Troubleshooting

Lesson 2: The Process of Troubleshooting

Lesson 2 of 2 Recommended Time: 45 minutes

Purpose: This lesson develops an approach to troubleshooting treatment plants called the *Process of Troubleshooting*. The *Process of Troubleshooting* is presented as five major phases which organize the procedure for gathering and analyzing data about the treatment plant to identify problem areas and their probable causes. Using the data gathered as a basis the procedure then leads to identification of solution alternatives which should be considered before recommending a course of corrective action. A priority system for rank ordering the potential solutions is introduced. Procedures to monitor the effectiveness of the corrective action are discussed. The process recognizes that many problems cannot be solved by O & M procedures alone but require more extensive corrective action such as design and construction of new facilities.

The *Process of Troubleshooting* is essential to the course because it provides a systematic framework which can be applied to identify problems at any wastewater treatment facility. The approach developed in this lesson is used throughout the course. Trainees who master the *Process of Troubleshooting* will possess a tool which can be applied to treatment facilities which experience problems which are not explicitly addressed in the course.

Trainee Entry Level Behavior: Trainees will have completed Unit 2, Lesson 1.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. From memory, list the five major steps in the *Process of Troubleshooting*, describe the activities which occur in each step and explain the significance of each activity to effective troubleshooting.

2. Using the flow charts, pages T2.2.9 and T2.2.10 in the *Trainee Notebook*, explain how the *Process of Troubleshooting* is applied to performance evaluation and problem solving at a wastewater treatment facility.

3. From memory, list at least five sources which the troubleshooter might use to obtain technical information about the design, operation and maintenance of a specific wastewater treatment facility.

4. From memory, list at least five sources which the troubleshooter might use to obtain technical information about wastewater treatment facility design, operations and maintenance in general.

5. From memory, list at least four criteria which may be used to measure the effectiveness of a technical assistance project and explain the significance of each criterion.

Instructional Approach: Illustrated lecture with class discussion. The instructor should follow the lesson outline provided.

Lesson Schedule: The 45 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 5 minutes	The Systematic Nature of Troubleshooting
5 - 15 minutes	Elements of Troubleshooting - Initial Steps
15 - 20 minutes	Formulating Alternative Solutions
20 - 25 minutes	Steps 3, 4 and 5, Elements of Troubleshooting
25 - 35 minutes	Applying the Process of Troubleshooting
35 - 45 minutes	Summary of Discussion

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T2.2.1 - T2.2.12.

2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, Sections 2 and 3, pages 3 - 13.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 2, Lesson 2, pages 2.2.1 - 2.2.8.

2. Slides 179.2/2.2.1 - 179.2/2.2.17.

Instructor Materials Recommended for Development: None suggested.

Additional Instructor References:

1. Hinricks, Daniel J., *Inspectors Guide for Evaluation of Municipal Wastewater Treatment Plants*, EPA/430/9-79-010, Municipal Operations Branch, Office of Water Program Operations, Environmental Protection Agency, Washington, D.C., (April, 1979).
2. *Instructor Notebook*, Unit 1: *Overview*, Lesson 3: The Significance of O & M.

Classroom Set-Up: As specified for Unit 2, Lesson 1.

LESSON OUTLINE

I. The Systematic Nature of Troubleshooting (5 min.)

- A. Troubleshooting must be systematic
  - 1. Many factors may affect plant performance:
    - a. Personnel
      - (1) Number of plant staff
      - (2) Competence of plant staff
      - (3) Coordination of plant staff activities
    - b. Maintenance
      - (1) Preventive maintenance program
      - (2) Repair/replacement of equipment
    - c. Process Control Procedures
      - (1) Understanding wastewater treatment operations
      - (2) Standard Operating Job Procedures (SOJPs)
      - (3) Laboratory
        - (a) Process Control
        - (b) NPDES Monitoring
      - (4) Applying laboratory results to plant process control
      - (5) Load variations
        - (a) Identification
        - (b) Process control response
    - d. Design of Facility
      - (1) Flexibility for process control responses.
      - (2) Adequacy of equipment
        - (a) Underloaded
        - (b) Overloaded

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/2.2.1

Slide 179.2/2.2.1 is a blank slide used to blacken the screen.

Refer to *Instructor Notebook*, Unit 1, Lesson 3: The Significance of O & M

Briefly relate each factor to potential impact on plant performance.

LESSON OUTLINE | KEY POINTS & INSTRUCTOR GUIDE

        (c) Obsolete
        (d) Misapplication

    (3) Expedients to improve operability of plant

  d. Facility Management

    (1) Relationship to community
    (2) Funding for O & M
    (3) Reporting and control systems
    (4) Adequacy of supervision

2. Several of the above usually occur simultaneously and all problem areas must be eliminated in a comprehensive technical assistance project to achieve optimum performance.

3. Many of the above factors may cause similar indicators or symptoms of problems.

4. Troubleshooting involves many skills:

  a. Relationship with operators

  b. Relationship with regulatory agencies

  c. Gathering technical data

  d. Analyzing technical data

  e. Recognizing problems

  f. Identifying problem causes

  g. Identifying alternative solutions

  h. Recommending solutions

  i. Implementing corrective action

  j. Evaluating success

LESSON OUTLINE

KEY POINTS &
INSTRUCTOR GUIDE

5. Troubleshooter must approach problem solving systematically to identify all problems, their causes and their cures.
    a. Attack simple problems first, then more complex problems.
    b. Eliminating the obvious problems may reveal a more serious underlying problem.
    c. Must priorize efforts if time is to be used efficiently.

B. Aids to Troubleshooters

1. There is no "pat" formula for troubleshooting but
2. There are a number of useful aids or guides to help troubleshooters:
    a. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities.*
    b. Inspection Checklists
        (1) Refer to *Trainee Notebook*, pages T2.2.1-T2.2.7.
        (2) This is only one example of a checklist which shows the type of data which must be considered.
    c. Inspection Forms
        (1) EPA Form 7500-5
        (2) State forms
        (3) Operating report forms

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
C. Basic Elements of Troubleshooting	Use Slide 179.2/2.2.2
1. Regardless of guide used, troubleshooting can be reduced to seven (7) basic elements.	Slide 179.2/2.2.2 reads: "Basic Elements of Troubleshooting
2. Refer to seven points made on Slide 179.2/2.2.2	* Review of plant conditions * Communication and observation * Analysis and testing
3. Briefly review points on Slide 179.2/2.2.2 with class. DO NOT READ THE SLIDE TO THE CLASS! PARAPHRASE TO CLARIFY!	* Formulation of alternative actions * Corrective actions - trial and error * Long range implementation * Monitor, document and follow-up"
D. To illustrate these elements, this course uses a chart called "The Process of Troubleshooting." This chart:	Refer class to *Trainee Notebook*, page T2.2. 8, The Process of Troubleshooting.
1. Will be used throughout the course in each lesson.	
2. Demonstrates the systematic nature of troubleshooting.	
3. Is not a formula or list to follow - experienced troubleshooters develop their own detailed procedure, but chart summarizes the essential features of a good troubleshooting approach.	
E. Questions and discussion on the systematic nature of troubleshooting.	
II. Elements of Troubleshooting - Initial Step - Analyzing and Learning (10 min.)	
A. Analyzing and Learning	Use Slide 179.2/2.2.3
1. Use Slide 179.2/2.2.3 to illustrate Line 1, Analyze and Learn, in the process of troubleshooting.	Slide 179.2/2.3.3 reads

LESSON OUTLINE

2. Note to class that before we get into Troubleshooting, we must ask:
   a. Do we have a problem?
   b. What is vs. what ought to be in the plant?

3. Ask class for input on indicators of problems. List below includes some items which might indicate problems.
   a. Not meeting NPDES permit
   b. Upsets which operator cannot control
   c. Excessive use of chemicals or energy
   d. Frequent equipment breakdowns
   e. Odors
   f. Sloppy housekeeping
   g. Unusual costs for treatment
      (1) Too high
      (2) Too low
   h. Citizen complaints
   i. Operators unhappy with the plant

KEY POINTS & INSTRUCTOR GUIDE

"The Process of Troubleshooting

Analyzing and Learning

A. Begin troubleshooting
B. Review information
C. Visit plant
D. Determine data needs
E. Analyze, sample and test
F. Process Test"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
(1) Too much work to keep plant going (2) High turnover in personnel	
4. Next several slides will go through activities included in the line Analyze and Learn	
B. Step A - Begin Troubleshooting	Use Slide 179.2/2.2.4
1. Ask class why the information on Slide 179.2/2.2.4 is important.	Slide 179.2/2.2.4 reads:
2. Answer Sought:	"'Begin Troubleshooting'
"How the troubleshooter gets called in may affect the approach to the problem and the plant's attitude about the troubleshooter."	Possible Circumstances of Troubleshooter Entry into Plant * Part of routine inspection * Request by plant operator * Complaint from citizens * Violation of permit conditions"
a. Routine inspection or plant visit may lead to informal exchange on ways to improve operation. Could reveal information which leads to	
b. Operator requesting in-depth assistance - the best of all worlds - you're there at the operator's request. He wants you therefore he'll be more receptive and cooperative as compared to a case when you're called in by management because	
c. There's been a complaint or a violation of the permit. The operator may not want you there, therefore, you may have to use all your skills to establish good cooperative relations with the operator.	
C. Step B - Review Information	Use Slide 179.2/2.2.5

LESSON OUTLINE

1. Troubleshooter must do his/her homework. Learn as much about the plant as possible before you start.
2. Ask class to list some of the kinds of information the troubleshooter should collect and to identify sources he/she might use to get the information.
3. Some possible types and sources of information:
    a. Plans and design of plant.
    b. Daily log, including maintenance and breakdowns.
    c. Results of process control tests.
    d. Results of NPDES monitoring.

D. Step C - Visit Plant

1. A site visit is essential!
2. Ask class to respond to questions on slide 179.2/2.2.6.
    a. Who should you meet?
        (1) Everybody! but
        (2) Determine who's in charge and who has what authority
    b. Who should you listen to?
        (1) Everybody!
        (2) Even the most lowly laborer may give you clues to potential problems which are not readily obvious.

KEY POINTS & INSTRUCTOR GUIDE

Slide 179.2/2.2.5 is a blank slide used to blacken the screen.

Turn up the lights.

Refer class to *Trainee Notebook*, page T2.2.8, The Process of Troubleshooting.

Dim Lights

Use Slide 179.2/2.2.6

Slide 179.2/2.2.6 reads:

"Visit Plant - Meet and Listen

Observe and Review

Who should you meet?
Who should you listen to?
What should you observe?
Why??"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
c. What should you observe?	
(1) Everything! (2) Housekeeping (3) Process control procedures (4) Maintenance procedures (5) Sampling and laboratory procedures (6) Reporting systems (7) Interaction between personnel (8) Relationship to City Hall	
E. Step D - Determine Data Needs	Use Slide 179.2/2.2.7
1. Use observations to key our identification of additional data we need to solve the problem.	Slide 179.2/2.2.7 is a blank slide used to blacken the screen.
a. Do we know what problems exist?	Turn lights up
b. Do we know the causes?	
2. If not, what samples, tests and analyses do we need?	
F. Step E - Analyze - Sample and Test	
Refer class to:	
1. *Trainee Notebook*, Checklist, pages T2.2.1 - T2.2.7.	
2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*	
for data required to evaluate overall system and individual processes.	
G. Step F - Process Test	
1. Modify some elements in the treatment processes and observe the effects after you have analyzed the data gathered earlier.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

2. This provides an opportunity to observe the responsiveness of the system to control changes.

3. May be able to accomplish this by observing the normal operating procedures at the plant.

4. Other lessons in the course deal with process tests in depth.

H. Useful sources of information for Troubleshooters.

1. Refer to *Trainee Notebook*, pages T2.2.11 - T2.2.12.

2. Review following briefly with class:

   a. In-plant information

      (1) Plant log and records
      (2) NPDES permit and monitoring data
      (3) Plant O & M manual

   b. EPA Materials

      (1) Inspection and evaluation forms
      (2) Peformance evaluation manual
      (3) Case histories - plant performance
      (4) Technology transfer and other technical information

   c. Other technical materials

      (1) State manuals and guidelines
      (2) WPCF

   d. Other persons who can be called for assistance

      (1) The operator

LESSON OUTLINE

(2) Other local people
(3) State specialists
(4) Federal specialists
(5) Operations consultants

e. Personal observations:

(1) Plant personnel and operators
(2) Physical conditions of plant
(3) Working conditions
(4) Inter-personal relationships
(5) Management behavior

f. Analyses and tests

(1) Compare plant performance to normal operating characteristics
(2) Sampling and testing program
(3) Process modification and testing

III. Elements of Troubleshooting - Formulating Alternative Solutions (5 min.)

A. Use Slide 179.2/2.2.8 to illustrate Line 2, Formulate Alternative Solutions, in the Process of Troubleshooting

B. Because many factors may affect plant performance and cause operational problems, several solution options must be considered to cure the problem.

C. Formulating alternative solutions is the most important thing you do as a troubleshooter and is a continuous process that

KEY POINTS & INSTRUCTOR GUIDE

Dim Lights

Use Slide 179.2/2.2.8

Slide 179.2/2.2.8 reads:

"Formulating Alternative Solutions

a. Initial Opinion - do we know the cause?
b. Opinion - reasoning leads to alternatives
c. Alternatives - consider types and impact of each
d. Priority alternatives
e. Confirm - with whom?"

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

begins very early in the troubleshooting project and runs parallel with the data acquisition phase.

1. Initial Opinion
    a. Usually highlights obvious problems and their causes.
    b. Is the obvious the true problem and the true cause?
    c. Care must be taken not to form rigid, preconceived ideas in the early phases of the project. Remain flexible and open.
2. Opinions and alternatives
    a. Data gathering and analysis provides clues to the depth of problems and their causes.
    b. Many problems manifest themselves with similar symptoms (data and observations).
3. Develop list of alternative causes and cures
    a. List all the possible causes for each problem.
    b. For each cause, list all the solution options available.
    c. Use available data to identify most likely causes and preferred solutions.
    d. Gather additional data, if needed, to sort through all potential causes and solutions.
    e. Combine above to develop

LESSON OUTLINE

D. Prioritized list of alternative solutions

1. Confirm opinions

a. Operator - must know what you're doing and why - must concur. The operator is the one who implements your recommendations.

b. If in doubt, seek help. Nobody knows everything. Don't be afraid to ask for advice when you need it and revise priority list if appropriate.

E. Now you're ready to implement your preferred solution.

IV. Elements of Troubleshooting - Steps 3, 4 and 5 (5 min.)

A. Corrective Actions

1. Remember the operator runs the plant! You are an advisor.

2. Make sure that you and the operator understand what you are doing and what to expect for each alternative on your list of possible solutions. For each solution you should know:

a. Why you're taking the actions recommended.

b. What everybody does. Make sure all personnel know their roles and their jobs and that they do them correctly.

c. What results to expect and when they should occur.

(1) Some actions cause a quick

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/2.2.9

Slide 179.2/2.2.9 reads:

"Elements of Troubleshooting

Corrective Actions

* Type of action to take
* Purpose of action
* Duration of the results
* Effect of action
* Should there be a combination of different actions for different purposes?"

LESSON OUTLINE

response, for example, changing the air flow rate to an aeration diffuser bank will cause a change in DO in a few minutes.

(2) Other changes occur very slowly. For example, if you change wasting rate in an activated sludge tank, several days or perhaps weeks may pass before the system fully stabilizes.

d. Is more than one corrective action indicated? Should they be implemented simultaneously? Normally change one thing at a time and wait to see what happens before making additional major changes. Too many changes at once may confuse the picture.

B. Observe and Test

1. After making a change, monitor the results:

   a. Observations

   b. Laboratory Data

   c. Other data

2. Refer to *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* for detailed information on testing and monitoring requirements for each process.

3. Evaluate the results.

   a. Have the goals of the project been accomplished?

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/2.2.10

Slide 179.2/2.2.10 reads:

"Observe and Test

* Which tests to make
* Evaluate the results
* Compare results with prior performance
* Are the desired results achieved? If not - select a different alternative"

LESSON OUTLINE

(1) Yes - you're through. Document your effort and go on to the next project.
(2) No - recycle back to your prioritized lists of causes and solutions. Reevaluate. Take next indicated action.

b. Did this success reveal other problems?

(1) Yes - What do I do now? Use the process of troubleshooting.
(2) No - Document your project and go on to the next problem.

C. Long Range Implementation

1. "Long Range" means things which cannot be corrected in the context of a limited technical assistance effort.

a. Substantial financing needed.

b. Design and major construction needed.

c. Things which can be done with available resources but require long times to do and do not require the troubleshooter's presence on the site throughout.

d. Substantial changes in personnel

(1) Long term training

(a) Technical
(b) Management

(2) Increase or change staffing (Personnel changes). Its hard to do but sometimes the only solution is to replace

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/2.2.11

Slide 179.2/2.2.11 reads:

"Long Range Implementation

Types of Measures Possible

- ★ Process or flow changes
- ★ Chemical additions
- ★ Design modifications
- ★ Repair or replace equipment
- ★ Cleaning and maintenance
- ★ Management changes"

LESSON OUTLINE

operating personnel who are not capable of managing and running the plant.

2. Some of these items will have been identified early in the data acquisition and analysis steps, Steps 1 and 2 of the process. The preferred alternative solution identified in Step 2D Prioritized Alternatives may be GO DIRECTLY TO A LONG TERM SOLUTION, Step 5.

3. Even though a "Long Term" solution may be needed to get optimum performance, plant management may opt to try to upgrade performance of the existing plant through various short term solutions, improved O & M, while implementing the "long term" solution.

D. Final Steps in Troubleshooting

1. It is essential that long term follow-up with the plant be maintained to monitor the success of the project and provide advice as needed. Follow-up may be by:

   a. Site visit.

   b. Telephone.

   c. Correspondence.

2. An over-riding objective of all troubleshooting projects is to develop plant staff capability to continue what the troubleshooter starts. If plant staff cannot continue successfully, the project has failed.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/2.2.12

Slide 179.2/2.2.12 reads:

"Final Steps in the Process of Troubleshooting

- * Monitor results
- * Document
- * Follow-up"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. All technical assistance projects should be documented. a. What was done? b. Why it was done? c. What results were achieved? d. What did it cost? e. What were the benefits? f. What else needs to be done and why? Documentation is a record which can be used as a resource in future projects by you and by others. The project's not complete until its documented.	Use Slide 179.2/2.2.13 Slide 179.2/2.2.13 is a blank slide used to darken the screen. Turn Lights Up
V. Applying the Process of Troubleshooting (10 min.) A. Troubleshooting or technical assistance can be viewed as a two-phased implementation: 1. Preliminary Evaluation Phase Obtain and evaluate preliminary data to make recommendations for more extensive assistance with preliminary resource estimates for management consideration and decision. 2. Troubleshooting Phase	

LESSON OUTLINE

Begins after management authorization and involves detailed analysis and solution of problems.

B. Preliminary Evaluation Phase

1. Refer class to *Trainee Notebook*, pages T2.2.9, "Flow Chart for the Preliminary Evaluation of a Wastewater Treatment Facility"

2. Steps in Preliminary Evaluation:

    a. Step 1. Begin.

    b. Step 2. Review design and historic performance data.

    c. Step 3. Tour plant, review and observe operation.

    d. Step 4. Determine waste characteristics and flows.

    e. Step 5. Answer question "Can the present equipment treat the waste?"

        (1) No - then list indicated problems and prepare preliminary recommendations.
        (2) Yes - go to Step 6.
        (3) Most plants will yield a "maybe" answer. Then both e(1) and e(2) must be done.

    f. Step 6. Answer question "Does the system meet NPDES permit?"

        (1) No - Go to Step 8.
        (2) Yes - Go to Step 7.
        (3) Sometimes - Go to both Steps 7 and 8.

    g. Step 7. Answer question "Is plant

KEY POINTS & INSTRUCTOR GUIDE

Expand on items as appropriate relating each step to the *Process of Troubleshooting*. These steps are the first actions under the "Analyze and Learn" and the "Formulate Alternative Solutions" steps in the Process of Troubleshooting.

performing at optimum and most economic operation?"

(1) No - Go to Step 8.
(2) Yes - Go to Step 9.

h. Step 8. List indicated problems and prepare recommendations.

i. Step 9. Report finding to management for decision.

j. Step 10. Management answers question "Is more extensive assistance required?"

(1) Yes - Go to Step 12. Begin technical assistance project.
(2) No. Your job is done. Go to Step 11, Job Complete. Do Not Pass Go. Do Not Collect $200.

C. Troubleshooting or Technical Assistance Phase

1. Refer class to *Trainee Notebook*, page T2.2.10, "Flow Chart for Troubleshooting a Wastewater Treatment Facility"

2. Steps in Troubleshooting:

   a. Step 12. Begin.

   b. Identify and correct design deficiencies.

      (1) Step 13. Answer question "Can present equipment treat the waste?"
         (a) No. Go to Step 14.
         (b) Yes. Go to Step 15.
         (c) Maybe. Go to Step 14.

See page T2.2.10

Expand as appropriate. These steps corresponde to establishing the "Prioritized List of Alternate Solutions" and "Implementation of Corrective Action" steps in the *Process of Troubleshooting*.

Several points in the flow chart require a decision by plant management. These are not shown separately but are inferred in block to implement corrective action.

LESSON OUTLINE

(2) Step 14. Answer question "Is present equipment operating at maximum efficiency?
  - (a) Yes. Go to Step 15.
  - (b) No or maybe. Ask management whether you should go to Step 15 or Step 16 or both?

(3) Step 15. Design and Construct modifications
  - (a) When complete, go to Step 13.
  - (b) The answer from Step 13 should now be yes.

c. Identify and Correct Mechanical (Maintenance) Problems

(1) Step 16. Answer question "Does present equipment operate properly?"
  - (a) No. Go to Step 17.
  - (b) Yes. Go to Step 18.

(2) Step 17. Identify and Correct cause of improper operation

  - (a) Identify and correct things as:

    1. Replace obsolete equipment.
    2. Repair breakdowns.
    3. Devise minor modifications to correct deficiencies.
    4. Institute good preventive maintenance program.
  - (b) When complete, return to Step 16.
  - (c) The answer to Step 16 should now be yes.

KEY POINTS & INSTRUCTOR GUIDE

Several decision blocks in the Preliminary Evaluation and Troubleshooting Phases are the same. The Troubleshooting Phase considers each in much more detail and depth to lead to specific recommendations.

d. Identify and Correct Process Control Deficiencies

(1) Step 18. Answer question "Are plant personnel properly trained?"

(a) Yes or maybe. Go to Step 20.
(b) No. Go to Step 19.

1. Step 19. Train operators.
2. Return to Step 18.

(2) Step 20. Answer question "Are Standard Operating Job Procedures (SOJPs) used to operate the plant?"

(a) Yes. Go to Step 23.
(b) No. Go to Step 21.

1. Step 21. Assist plant management to develop good SOJPs, then go to Step 22.
2. Step 22. Assist management to implement improved systems and procedures, then go to Step 18. (You may have to train the operators in the new procedures.) Eventually you get through Steps 18 and 20 with all yes answers and go to Step 23.

(3) Step 23. Answer question "Are SOJPs correct?"

Key Point: Management must define standard procedures for performing various jobs at the plant. All personnel must perform their jobs correctly in accordance with the standard procedures. This helps assure that all jobs are done the same way every time they are performed regardless of who performs the task.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
(a) Yes. Go to Step 24. (b) No. Go to Step 21, then Step 22 and then Step 18 until a yes answer is obtained at Step 23.	
e. Identify and Correct Management Deficiencies.	
(1) Step 24. Evaluate operations with trained operators and good SOJPs.	Note: At this point equipment should be adequate and in good working condition, the operators are trained and the system is being operated using correct process control procedures. Hence problems that remain must be due to some other cause. The only thing left is management.
(2) Step 25. Answer question "Does plant meet NPDES permit?"	Note: A priority objective must be to get the plant into compliance.
(a) Yes. Go to Step 28. (b) No. Go to Step 26 and ask question "Are management systems and supervision adequate?	
1. Yes. Return to Step 13 and check out system again.	Note: Frequently correction of process control problems will disclose other deficiencies which were masked by the poor process control.
2. No. Go to Step 27.	
a. Step 27. Assist management to develop improved management and supervisory systems.	Note: Identifying and solving management problems may disclose other problems which were hidden previously.
b. Then go to Step 22. Assist management to	The management problem may be outside the treatment plant. The problems could be in City

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
implement improved systems and procedures.	Hall. You're now in an area where all your finesse and skill must be used.
c. Then go to Step 18 because plant personnel may need training in the new procedures. Management training may be needed.	
d. If all goes well, work back to Step 25 and get a yes answer so that you can go to block 28.	
(3) Step 28. Answer question "Is plant performing at optimum and most economic efficiency?"	Note: Many state and federal regulatory agency personnel consider their job done once the plant is in compliance with NPDES permit conditions. The job's not done until the plant performs efficiently, i.e., the best treatment for the lowest cost.
(a) Yes. Go to Step 29.	
(b) No. Go to Step 26 and work back through the process to correct any remaining deficiencies which keep the plant from performing at peak efficiency. Eventually you get back to Step 28, get a yes answer and can go to Step 29.	Note: Achievement of the objective specified in Step 28 should be the highest priority of plant management. Management's continuing job is to ask the question in Step 28 and to fine tune the system so that the answer is always YES! THE PLANT IS PERFORMING AT PEAK EFFICIENCY!
f. Step 29. Prepare Final Report	

(1) Documentation is essential.

LESSON OUTLINE

(2) Consultants and regulatory agency personnel need records of their accomplishments.
(3) Plant superintendents need to let their superiors know what a great job they are doing. Preparing the annual report should be viewed as a priority and an opportunity by the plant superintendent.

g. Step 30. Job complete.

C. Discussion

1. Ask trainees to relate the *Process of Troubleshooting* to their own experiences.

2. Determine whether approaches included in the *Process of Troubleshooting* resemble those used by the trainee.

3. Try to get discussion from:

   a. Regulatory Agency person.

   b. Consultant person.

   c. Plant Superintendent

VI. Review and Summary of Unit 2 (10 min.)

A. Troubleshooting Goals

1. Define goals before you begin troubleshooting project.

2. Preliminary evaluation is really used to set project goals.

3. Goals will determine:

KEY POINTS & INSTRUCTOR GUIDE

Turn Lights Up

Use Slide 179.2/2.2.14

Slide 179.2/2.2.14 reads:

"Results Should Reflect Goals
Know what you're trying to do!

* Solve immediate breakdown or problem
* Prevent reoccurrence
* Improve long-run O & M
* Upgrade plant performance"

a. Financial resources needed.

b. People needed

  (1) Number
  (2) Skills

c. Time needed

4. Use Slide 179.2/2.2.14 to illustrate some troubleshooting project goals. Ask class to identify others.

5. Emphasize that approach must be systematic to achieve goals.

B. Troubleshooter Effectiveness

1. Both *human* and technical skills are required.

2. The troubleshooter is there to assist the operator.

3. Use Slide 179.2/2.2.15 to highlight constraints on troubleshooting if it is to be effective.

   a. Operator must be able to continue what the troubleshooter starts.

   b. Recommendations must be consistent with owner's resources.

   c. The plant must be physically capable of treating the waste.

   d. There should be a long-range impact, i.e., the plant personnel can continue what you start.

   e. Ask the class to add any other constraints.

Use Slide 179.2/2.2.15

Slide 179.2/2.2.15 reads:

"Effective Technical Assistance

* Accepted and understood by the operator
* Feasible, in both $ and manpower resources for the plant
* Within the plant capacity and design
* Of long range value to the plant
* ???

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
4. Inability to satisfy the four points on Slide 179.2/2.2.15 is tantamount to failure in the technical assistance project.	
C. Summary	Use Slide 179.2/2.2.16
Use Slide 179.2/2.2.16 to summarize key points in Unit 2.	Slide 179.2/2.2.16 reads: "Troubleshooting Requires *human* and technical skills Needs *positive* human behavior Must be *systematic* Can be approached through the *Process of Troubleshooting* Must be *acceptable* and *feasible*"
D. Discussion	Use Slide 179.2/2.2.17
1. Use any remaining time for class discussion.	Slide 179.2/2.2.17 is a blank used to blacken the screen.
2. Direct class to next activity in the course agenda.	Turn Lights Up

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 2: Elements of Troubleshooting

Lesson 2: The Process of Troubleshooting

Trainee Notebook Contents

Inspection Checklists T2.2.1

Detailed Inspection Checklist T2.2.2

Flow Chart - The Process of Troubleshooting T2.2.8

Flow Chart - For Preliminary Evaluation of a Wastewater Treatment Facility T2.2.9

Flow Chart - For Troubleshooting a Wastewater Treatment Facility T2.2.10

Sources of Information for Troubleshooters T2.2.11

INSPECTION CHECKLISTS[1]

Pre-Inspection Preparation Checklist

- Review past inspection reports
- Review as-built plant drawings
- Review plant flow diagrams
- Review plant performance records
- Review plant design parameters

Routine Inspection Checklist

The following items should be considered during a routine inspection:

- Plant site maintenance, including landscaping, fencing and buffer zone
- Plant aesthetics, including odors, building maintenance and painting requirements of outside visible structures
- Plant operation and maintenance records
- Plant staffing for operation and maintenance
- Plant laboratory, including equipment, test procedures and staff
- Plant influent
- Plant effluent
- Equipment records
- Safety equipment
- Sampling locations, methods and frequency
- Solids disposal, both grit and digested sludge
- Plant bypass frequency
- Infiltration/inflow

---

[1] This checklist is reproduced from Appendix B, "Basic Elements of State/Federal Programs on Operation & Maintenance of Municipal Wastewater Treatment Facilities," CH2M HILL, report to U.S. EPA, 3 February, 1975.

DETAILED INSPECTION CHECKLIST

The detailed inspection checklist outline is based on unit operations. For each individual plant, consideration should be given only to those unit operations relevant to that specific plant.

General

- Consider all items outlined on the "Routine Inspection Checklist"

Screening and Comminution

- Clean area
- Odors
- Storage of screenings
- Frequency of removal
- Maintenance of mechanical equipment

Grit Removal

- Amount of grit removed
- Amount of grit in other plant units
- Volatile solids in grit
- Maintenance of mechanical equipment
- Clean area
- Odors
- Adequate venting of grit chamber for enclosed areas; explosive or toxic gases
- Explosion-proof lights and other items in enclosed areas

Sedimentation Basins

- Clean area
- Safety railings
- Maintenance of mechanical equipment
- Odor problems
- Corrosion on metal and concrete
- Floating sludge or gas bubbles
- Frequency of scum removal and if scum is allowed to accumulate on scum barrier
- Raw sludge pump maintenance and cycling frequency
- Pressure gauges (are they provided on sludge pumps?) - this gives operation conditions and tells of stoppages in sludge lines
- Plugging in sludge lines and valves
- Raw sludge removal and percent solids content
- Percentage removal of SS and BOD

Biological Treatment Units

Trickling Filters

- Dosing performance
- Filter flies and odors
- Corrosion of piping
- Maintenance of equipment
- Clogging of nozzles
- Condition of filter media
- Cleaning program of underdrains

- Performance of final clarifiers (similar to primary sedimentation outline)
- Frequency of sludge handling from high rate system, as it becomes septic faster than from standard system
- Recirculation volumes
- Condition of biological growth on filter media
- DO of effluent
- Icing of filter surface if inspection is performed in cold climatic regions

Activated Sludge Process

- Frothing in aeration tank
- Corrosion
- Maintenance of equipment such as blowers, filters, diffusers, air lines, sludge pumps and scrappers
- MLSS in aeration tank; color, foam, odor, etc.
- Flow and concentration of return sludge
- DO in aeration tank
- Bulking sludge in final clarifier
- Rising sludge in final clarifier
- Waste sludge flow
- Sludge depths in hoppers and cycling rates of the sludge pumps
- Condition of launders on final clarifier
- Sludge valves and lines for sign of plugging
- Final clarifiers for skimmings removal
- Safety measures, such as guard rails

Chlorination

- Chlorine requirements based on effluent chlorine residual requirements and coliform organisms
- Equipment maintenance and pipe corrosion
- Safety measures such as gas masks, separate ventilation of chlorine feed rooms, explosion-proof electrical fixtures to prevent corrosion, storage of chlorine cylinders and capped valves on chlorine cylinders
- Check method and frequency of cleaning chlorine contact table

Sludge Digestion

- Raw sludge solids concentration
- Percent volatile matter in raw sludge
- Temperature ranges of operation
- Sludge pumps for operation and maintenance
- pH control
- Mixing and/or recirculation
- Safety measures
- Gas production
- Percent reduction of volatile matter for digesting process
- Quality of supernatant for volatile acids, alkalinity, BOD, SS
- Supernatant withdrawal and recycled back into plant headworks

Sludge Thickening and Conditioning

- Process used, such as gravity, elutriation, dissolved air flotation or chemical coagulation
- Proper lab tests conducted, depending on the process
- Equipment operation and maintenance
- Solids uniformity and grit
- Process efficiency
- Odors, oils and greases
- Clean area

Sludge Dewatering

- Process such as drying beds, vacuum filters, filter presses or centrifuges
- Equipment operation and maintenance
- Clean area
- Odors, oils and greases
- Check that adequate laboratory tests are conducted depending on dewatering process used

Sludge Disposal

- Process such as incineration, sanitary landfilling or soil conditioner
- Equipment operation and maintenance
- Odor and storage area
- Clean area

Equipment (General)

- Operation and maintenance records of all major equipment
- Adequate spare parts inventory
- Manufacturer's parts and operation and maintenance manuals of all major equipment
- Operation and maintenance of equipment according to manufacturer's recommendations
- Excessive downtime
- Preventive maintenance program
- Calibration of instruments
- Operation and maintenance of instruments

Records (General)

- Availability at plant of as-built design drawings
- Availability of operational records
- Availability of laboratory records
- Data management procedures

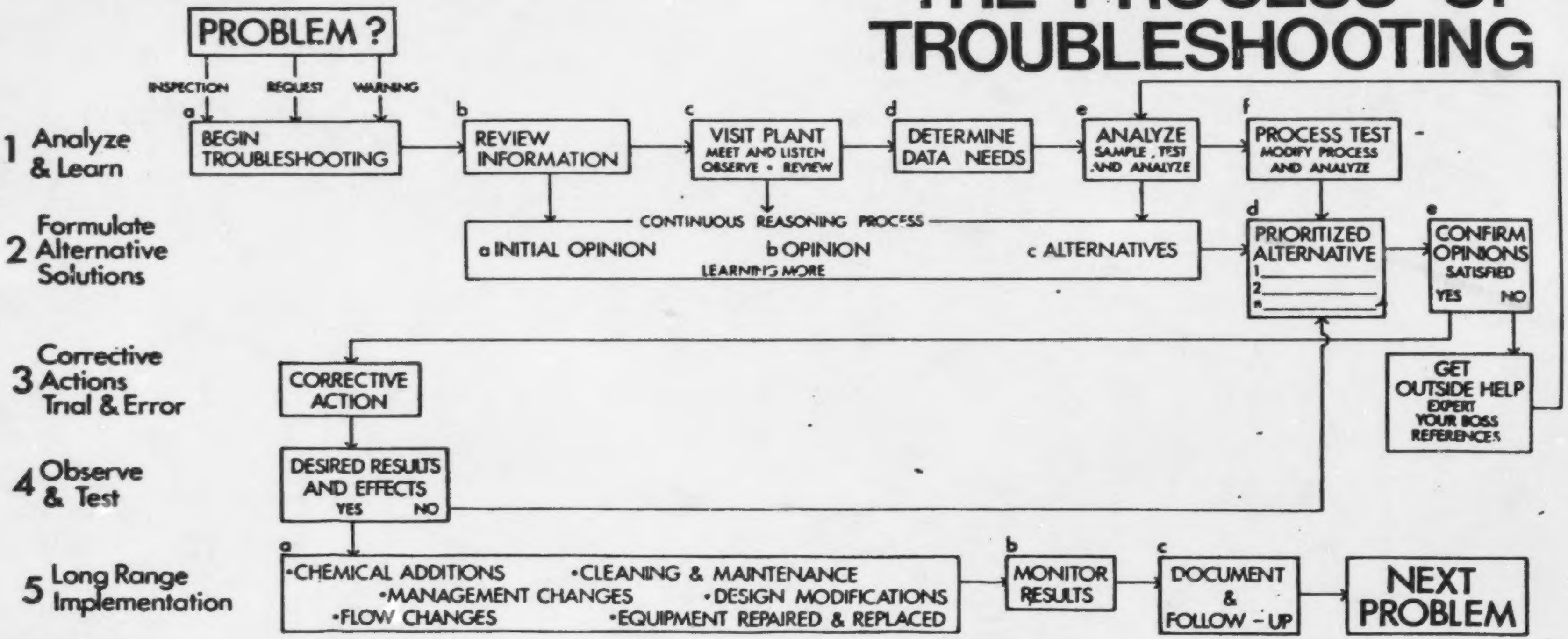
Staffing (General)

- Adequate staff available at facility for both the plant and laboratory
- Certification of plant operators
- Training programs for staff operators
- Shift requirements for operators
- Adequate administrative staff and supervision
- Adequate salaries for staff

T2.2.7

THE PROCESS OF TROUBLESHOOTING

T2.2.8



PROBLEM ?

INSPECTION
REQUEST
WARNING

1 Analyze & Learn

a BEGIN TROUBLESHOOTING

b REVIEW INFORMATION

c VISIT PLANT
MEET AND LISTEN
OBSERVE • REVIEW

d DETERMINE DATA NEEDS

e ANALYZE
SAMPLE, TEST AND ANALYZE

f PROCESS TEST
MODIFY PROCESS AND ANALYZE

2 Formulate Alternative Solutions

CONTINUOUS REASONING PROCESS

a INITIAL OPINION
b OPINION
c ALTERNATIVES

LEARNING MORE

d PRIORITIZED ALTERNATIVE
1.
2.
n.

e CONFIRM OPINIONS
SATISFIED
YES NO

GET OUTSIDE HELP
EXPERT
YOUR BOSS
REFERENCES

3 Corrective Actions Trial & Error

CORRECTIVE ACTION

4 Observe & Test

DESIRED RESULTS AND EFFECTS
YES NO

5 Long Range Implementation

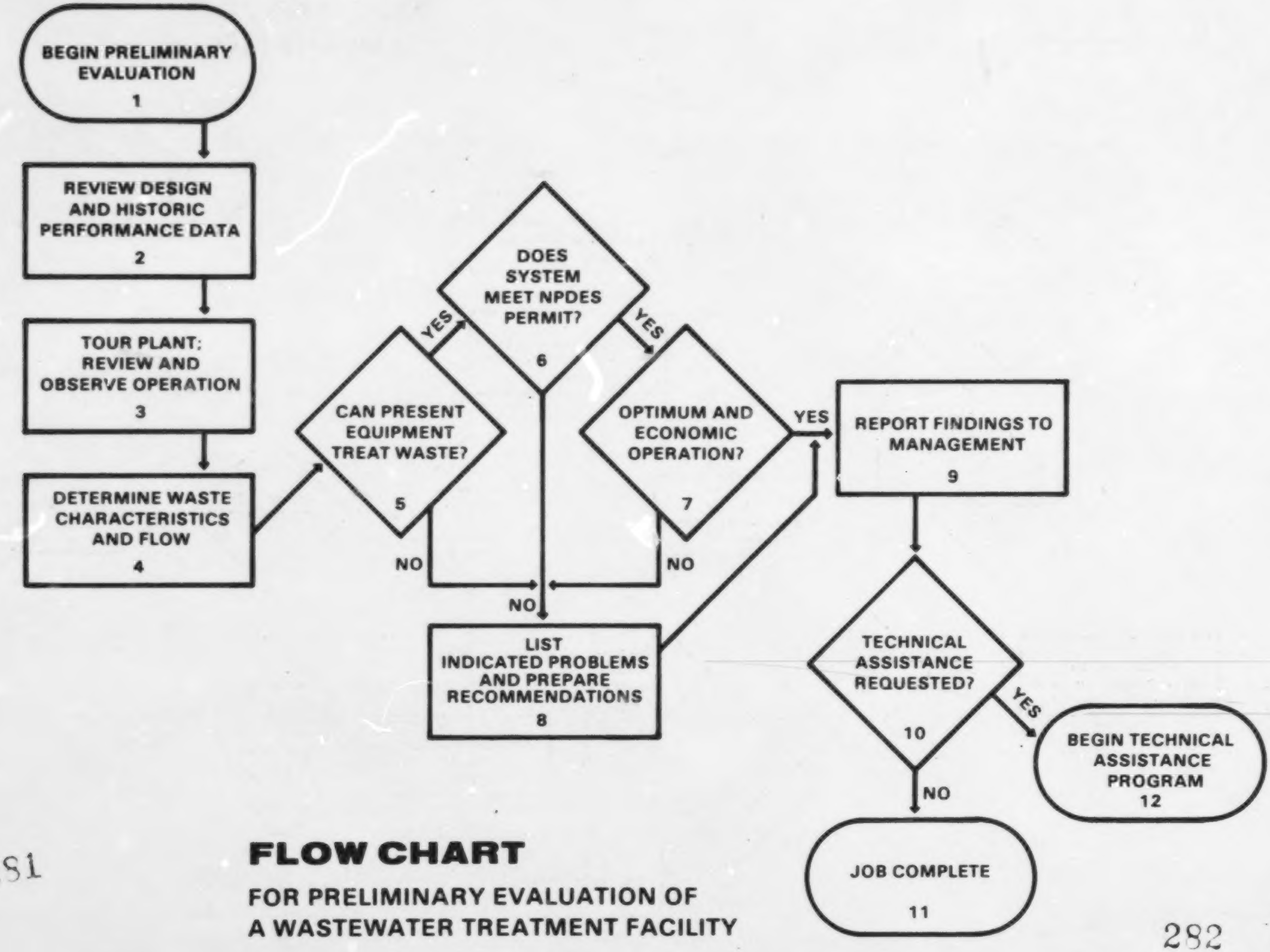
a
- CHEMICAL ADDITIONS
- CLEANING & MAINTENANCE
- MANAGEMENT CHANGES
- DESIGN MODIFICATIONS
- FLOW CHANGES
- EQUIPMENT REPAIRED & REPLACED

b MONITOR RESULTS

c DOCUMENT & FOLLOW - UP

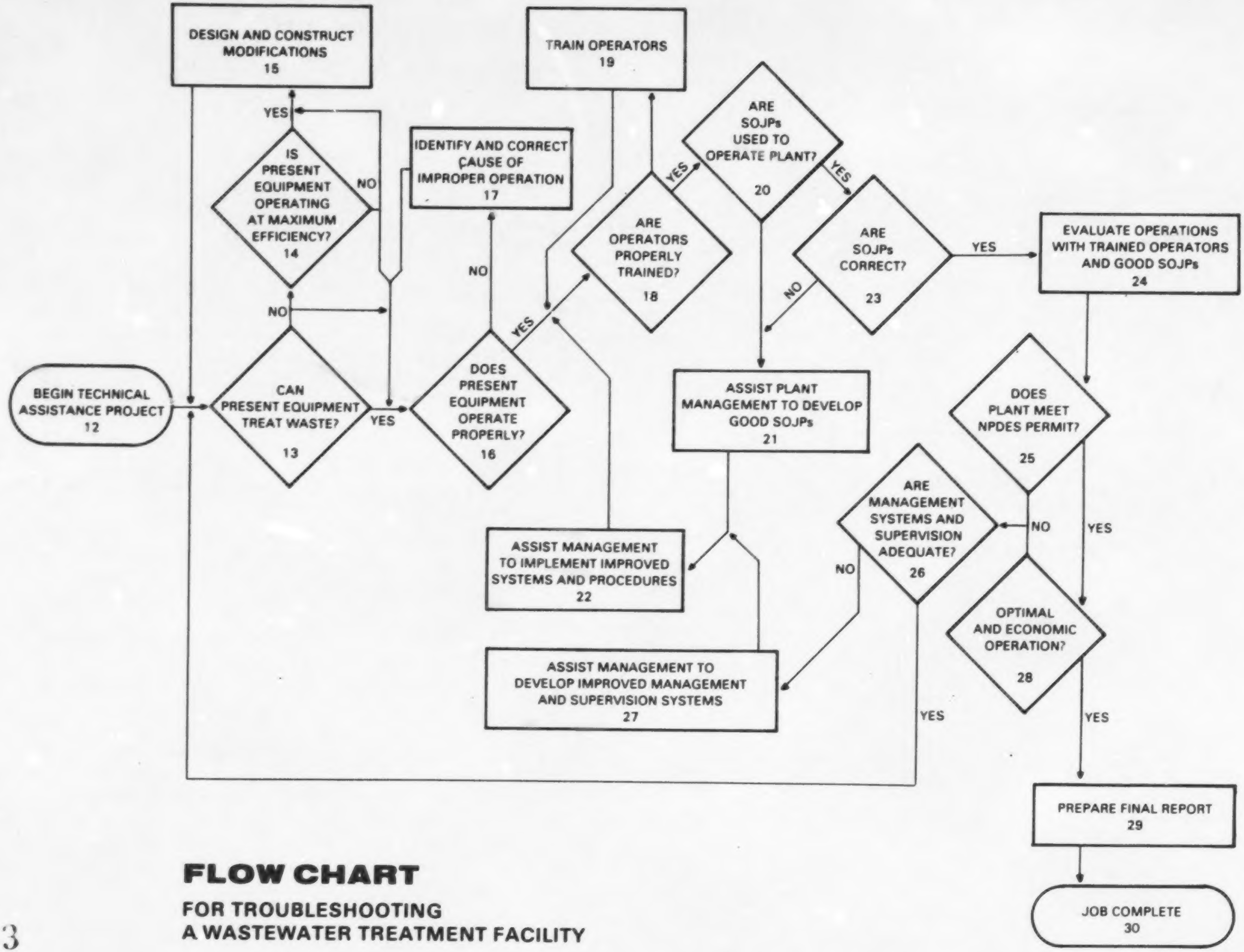
NEXT PROBLEM

T2.2.9


BEGIN PRELIMINARY EVALUATION
1
REVIEW DESIGN AND HISTORIC PERFORMANCE DATA
2
TOUR PLANT; REVIEW AND OBSERVE OPERATION
3
DETERMINE WASTE CHARACTERISTICS AND FLOW
4
CAN PRESENT EQUIPMENT TREAT WASTE?
5
YES
NO
DOES SYSTEM MEET NPDES PERMIT?
6
YES
NO
OPTIMUM AND ECONOMIC OPERATION?
7
YES
NO
LIST INDICATED PROBLEMS AND PREPARE RECOMMENDATIONS
8
REPORT FINDINGS TO MANAGEMENT
9
TECHNICAL ASSISTANCE REQUESTED?
10
YES
NO
BEGIN TECHNICAL ASSISTANCE PROGRAM
12
JOB COMPLETE
11

FLOW CHART

FOR PRELIMINARY EVALUATION OF
A WASTEWATER TREATMENT FACILITY


BEGIN TECHNICAL ASSISTANCE PROJECT 12
CAN PRESENT EQUIPMENT TREAT WASTE? 13
NO
YES
IS PRESENT EQUIPMENT OPERATING AT MAXIMUM EFFICIENCY? 14
YES
NO
DESIGN AND CONSTRUCT MODIFICATIONS 15
DOES PRESENT EQUIPMENT OPERATE PROPERLY? 16
NO
YES
IDENTIFY AND CORRECT CAUSE OF IMPROPER OPERATION 17
ARE OPERATORS PROPERLY TRAINED? 18
YES
TRAIN OPERATORS 19
ARE SOJPs USED TO OPERATE PLANT? 20
YES
ASSIST PLANT MANAGEMENT TO DEVELOP GOOD SOJPs 21
ASSIST MANAGEMENT TO IMPLEMENT IMPROVED SYSTEMS AND PROCEDURES 22
ARE SOJPs CORRECT? 23
NO
YES
EVALUATE OPERATIONS WITH TRAINED OPERATORS AND GOOD SOJPs 24
DOES PLANT MEET NPDES PERMIT? 25
NO
YES
ARE MANAGEMENT SYSTEMS AND SUPERVISION ADEQUATE? 26
NO
YES
ASSIST MANAGEMENT TO DEVELOP IMPROVED MANAGEMENT AND SUPERVISION SYSTEMS 27
OPTIMAL AND ECONOMIC OPERATION? 28
YES
PREPARE FINAL REPORT 29
JOB COMPLETE 30

FLOW CHART

FOR TROUBLESHOOTING A WASTEWATER TREATMENT FACILITY

SOURCES OF INFORMATION FOR TROUBLESHOOTERS

1. In-plant information
   - A. Plant log and records
   - B. NPDES Permit
   - C. Plant O & M Manual
   - D. Design reports, records, plans and specifications

2. EPA Materials
   - A. Inspection and evaluation forms, EPA Form 7500-5
   - B. "Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities"
   - C. Technology Transfer and other technical information
   - D. NTOTC training materials

3. Other technical resources
   - A. The operator
   - B. Other local people
   - C. State specialists
   - D. Federal specialists
   - E. Operations consultants
   - F. Technical journals and reports

4. Personal observations
   - A. Plant personnel and operators
   - B. Physical conditions of plant
   - C. Working conditions

T2.2.11

   - D. Interpersonnel relationships
   - E. Management behavior

6. Analyses and tests
   - A. Compare plant performance to normal operating characteristics
   - B. Sampling and testing program
   - C. Process modification and testing

Unit of Instruction 3: Sewer Use Control

Unit 3 of 15 Units of Instruction

Lessons in Unit: 2 Recommended Time: 1 3/4 hours

Instructor Overview of the Unit

Rationale for Unit: Many problems affecting wastewater treatment facilities are caused by uncontrolled discharges into the collection system or failure to maintain the collection system. This unit focuses on problems which originate in the collection system and procedures which may be used to achieve sewer use control. The unit emphasizes federal regulations relating to industrial pretreatment and industrial waste monitoring and discusses the role of the troubleshooter to assist communities plan and implement effective industrial waste control programs.

Trainee Entry Level Behavior: Trainees should have completed Unit 2, *Elements of Troubleshooting*, before beginning Unit 3, *Sewer Use Control.*

Trainee Learning Objectives: At the conclusion of this Unit of Instruction, the trainee will be able to:

1. Given a written statement of a plant operating problem, apply the *Process of Troubleshooting* to the analysis of the problem, correctly identify that the problem is caused by uncontrolled sewer use and recommend appropriate corrective measures to solve the problem.

2. From memory, describe the importance of sewer use control to improve overall wastewater treatment system performance.

3. Using references and class notes, cite at least three measures which can be used to evaluate the effectiveness of operations and maintenance of the collection system.

4. From memory, name at least one self-study training program which can be used to upgrade the skills of wastewater collection personnel.

5. Using references and class notes, list the requirements of the Federal regulations on industrial waste pretreatment and industrial waste monitoring.

6. Using references and class notes, list the steps in organizing and conducting an industrial waste survey.

7. Using references and class notes, list the major provisions which should be included in a sewer use control ordinance and explain the importance of each provision to monitoring and control of sewer use.

8. From memory, describe when and how the sewer use control ordinance can be used to improve wastewater treatment system performance.

9. Using references and class notes, assist municipalities in preparing, using and enforcing sewer use control ordinances and industrial waste monitoring and pretreatment programs.

Sequencing and Pre-Course Preparation for the Unit: The unit on Sewer Use Control is presented as two lessons.

Lesson 1: Applying the Process of Troubleshooting to Collection System Problems

Recommended Time: 60 minutes

Purpose: Use the *Process of Troubleshooting* to evaluate two wastewater treatment plant performance problems, determine data needed to identify the causes of the problems, identify the causes as being in the collection system and recommend appropriate corrective actions.

Training Facilities:

a. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees in groups of four;

b. Instructor table with lectern;

c. Large projection screen (6' x 6' minimum) and chalkboard in front of room and readily visible to all trainees;

d. Easel with pad;

e. 35 mm carousel projector with remote control changer at instructor table;

f. At least four empty carousel trays;

g. Overhead projector;

h. Chalk, felt-tip markers and erasers;

i. Six to eight chairs randomly spaced at back and sides of room for visitors.

Pre-Course Preparation: Reproduce and have available as handouts the following pages:

1. H3.1.1, "Problem Number 1, Fact/Answer Sheet Number 1."
2. H3.1.2, "Problem Number 1, Fact/Answer Sheet Number 2."
3. H3.1.3, "Problem Number 1, Fact/Answer Sheet Number 3."
4. H3.1.4, "Problem Number 2, Fact/Answer Sheet Number 1."
5. H3.1.5, "Problem Number 2, Fact/Answer Sheet Number 2."
6. H3.1.6, "Problem Number 2, Fact/Answer Sheet Number 3."
7. H3.1.7 - H3.1.10, "Solution to Problems."

Instructional Approach: Team problem solving in trainee work groups.

Lesson 2: Sewer Use Control and Industrial Waste Monitoring

Recommended Time: 45 minutes

Purpose: Stress the importance of proper sewer use control and industrial waste monitoring in obtaining optimum performance from a wastewater treatment facility, introduce the basic elements of sewer use control programs, and outline industrial waste pretreatment and monitoring program requirements.

Training Facilities: As specified in Unit 3, Lesson 1.

Pre-Course Preparation: Reproduce and place in *Trainee Notebook:*

1. Pages T3.2.1 - T3.2.4, "Collection System Conditions Affecting Treatment Operations."

2. Pages T3.2.5 - T3.2.11, "EPA's New Pretreatment Program."

3. Pages T3.2.12 - T3.2.18, "The Impact of Toxic Pollutants on Disposal from Wastewater Systems."

4. Pages T3.2.19 - T3.2.21, "Industrial Waste Survey."

5. Pages T3.2.22 - T3.2.27, "Example Sewer Use Control Ordinance."

Instructional Approach: Illustrated lecture.

Presentation Options for the Course Director: The Course Director has considerable flexibility in the use of Unit of Instruction 3, *Sewer Use Control.*

The order of the two lessons can be readily reversed to permit discussion of Sewer Use Control prior to trainee problem solving. The course developers suggest that the problem solving occur first so that trainees see that a plant performance problem is in reality a collection system problem and that trainees practice the *Process of Troubleshooting* immediately after Unit of Instruction 2 has been presented.

Unit of Instruction 3, *Sewer Use Control,* could be presented as a single lesson of 45 minute duration by dropping either lesson from the Unit. Either lesson could stand independently depending on the objectives of a given course.

Also, the course developers have deleted the Unit in its entirety from several presentations of the course. The deletion of the unit is acceptable if other Units of Instruction on wastewater treatment process units are modified to illustrate the impact of collection system deficiencies on wastewater treatment facility performance.

Summary of Unit of Instruction 3: *Sewer Use Control*

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Applying the Process of Troubleshooting	1. Apply the Process of Troubleshooting	1. The Process of Troubleshooting	1. Present two problems to class in three stages	1. *Instructor Notebook*, pages H3.1.1-H3.1.6
60 minutes	2. Analyze treatment problems caused by collection system	2. Collection system effects on treatment facility performance	2. Guide trainees during problem solving	2. *Instructor Notebook*, pages H3.1.7-H3.1.10
		3. Problem solving in teams	3. Lead class discussion of findings	3. *Trainee Notebook*, page 2.2.8
			4. Distribute problem solutions	
2. Sewer Use Control and Industrial Waste Monitoring 45 minutes	1. Identify effects of collection system on treatment facility performance	1. Importance of sewer use control to treatment facility performance.	1. Follow Lesson Outline using slides and key	1. Slides 179.2/3.2.1-179.2/3.2.13
	2. Give criteria for evaluating collection system	2. Requirements for industrial pretreatment and waste monitoring	2. Trainee discussion at appropriate points	2. *Trainee Notebook*, pages 3.2.1 - 3.2.29.
	3. Review EPA regulations on pretreatment & industrial waste monitoring	3. Contents of sewer use ordinance	3. Reference to *Trainee Notebook*	
	4. Assist in preparing and enforcing sewer use ordinance	4. Sources of information on collection system O & M		

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 3: Sewer Use Control

Lesson 1: Applying the Process of Troubleshooting to Collection System Problems

Lesson 1 of 2 Recommended Time: 60 minutes

Purpose: This lesson requires the class to apply the *Process of Troubleshooting* to analyze and solve two wastewater treatment facility performance problems. Problem answer sheets guide the class through the steps of the *Process of Troubleshooting.* A series of three fact sheets provide data needed to identify the cause of the problem and to recomment appropriate solutions. The performance problems are caused by collection system deficiencies which stresses to the trainee the need to consider the total system from waste source to collection system to treatment in analyzing performance problems.

Trainee Entry Level Behavior: Trainees will have completed Unit 2, *Elements of Troubleshooting*, before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson the trainee will be able to:

1. Given a written description of a performance problem at a wastewater treatment facility, apply the *Process of Troubleshooting* by successfully completing the following:
    a. Identifying sources of information about the problem,
    b. Identifying data needed to analyze the problem,
    c. Analyzing the data provided,
    d. Identifying the cause of the problem, and
    e. Recommending appropriate corrective actions.
2. Work successfully with members of his/her work group to analyze the problem assigned to the work group.

3. Recognize that infiltration/inflow and uncontrolled industrial waste discharges can cause wastewater treatment facility performance problems and that it is essential to consider the waste source, the collection system and the treatment facility as a total system in analyzing performance problems.

4. When called upon by the instructor, give an oral report of the findings of his/her work group.

Instructional Approach: Problem solving in four person work groups and discussion of findings.

Lesson Schedule: This 60 minute lesson is structured for half the class solving problem 1 and the other half to solve problem 2. The schedule for the lesson is:

TIME	ACTIVITY
0 - 10 minutes	Trainees Work with Fact/Answer Sheet #1
10 - 20 minutes	Trainees Work with Fact/Answer Sheet #2
20 - 30 minutes	Trainees Work with Fact/Answer Sheet #3
30 - 45 minutes	Discuss Problem #1
45 - 60 minutes	Discuss Problem #2

Trainee Materials Used in Lesson: *Trainee Notebook*, page 2.2.8, The Process of Troubleshooting.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 3, Lesson 1, pages 3.1.1 - 3.1.15.

2. *Instructor Notebook*, pages H3.1.1 - H3.1.6 will be used as individual handouts and should be reproduced so that each trainee gets one copy of each page. These pages should not be collated or stapled.

3. *Instructor Notebook*, pages H3.1.7-H3.1.10.

Instructor Materials Recommended for Development: The instructor may substitute problems from his own experience for those included in the lesson. Problems should be structured so that trainees apply the steps in the *Process of Troubleshooting* (Unit 2, Lesson 2). Only treatment system performance problems caused by collection system deficiencies should be used.

Additional Instructor References: None

Classroom Set-Up:

1. As specified in Instructor Overview to Unit, page 3.2 - 3.3.
2. Trainees should be seated with their assigned work group. Chairs and tables should be arranged to encourage discussion within work groups because groups work jointly on problems.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Background for Instructor	
A. Four person trainee work groups are assigned as a troubleshooting team to analyze and solve the problems which you will distribute to them.	
B. Information about the problems will be distributed in three stages. Trainee activities in each stage include:	
1. First Stage. Trainees are given fact/answer sheet no. 1 which contains very little information, only that the plants lose solids in the effluent. Both operators describe their problem as sludge bulking. The trainee groups are to complete the first answer sheet which requires them to plan their approach to the problem.	*Instructor Notebook*, page H3.1.1 and page H3.1.4.
2. Second Stage. Trainee groups are given the second fact/answer sheet which contains data obtained by visiting the community and visually observing conditions. In this stage, students attempt to identify the specific problem. Upon making the determinations, students should check with the instructor before going on to stage 3. As the trainee groups complete stage 2, they should identify that the problems are caused in the collection system. The instructor should provide assistance to allow them to go on to stage 3.	*Instructor Notebook*, page H3.1.2 and page H3.1.5.
3. Third Stage. Trainee groups are to recommend possible corrections to the problems and list those items they would observe to see if the problem has been corrected.	*Instructor Notebook*, page H3.1.3 and page H1.3.6.

C. Both problems are caused by collection system deficiencies.

   1. Problem No. 1 is inflow caused by basement sump pumps.

   2. Problem No. 2 is caused by an industrial waste discharge.

D. The instructor should present the problems to the class with a minimum of introduction. Under no circumstances should the instructor clue the class that these are collection system problems. Let the class learn this as they analyze the data given.

E. The purposes of this exercise in priority order are:

   1. Practice applying the Process of Troubleshooting.

Refer to *Trainee Notebook*, page T2.2.8.

   2. Practice working as a team.

   3. Identify that some performance problems are not caused or solved in the plant and that the plant is one part of a larger system.

II. Pre-Lesson Preparation

A. Duplicate and have available for distribution *Instructor Notebook*, pages H3.1.1 - H3.1.6. Do Not Collate or Staple These Pages!

B. Duplicate and have available for distribution *Instructor Notebook* pages H3.1.7 - H3.1.10. These pages should be collated and stapled. They will be distributed at the end of the lesson.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
C. Have class seated in four-person work groups. Number groups sequentially 1, 2, 3, 4, etc.	
III. Trainees Work With Fact/Answer Sheet No. 1 (10 min.)	
A. Have trainees remove pages T2.2.8, the Process of Troubleshooting, from their *Trainee Notebook* for use in the problem.	
B. Distribute Fact/Answer Sheet No. 1	*Instructor Notebook*, pages H3.1.1 and H3.1.4.
C. Assign odd numbered groups to work on problem number 1, page number H3.1.1.	
D. Assign even numbered groups to work on problem number 2, page number H3.1.4.	
E. Instruct groups that they are to work as a team and that they are to follow the Process of Troubleshooting to solve their assigned problem. The Fact/Answer sheet lists the specific things they are to do.	
F. Inform the class that they have 10 minutes to work on Fact/Answer Sheet No. 1. and that you will distribute another Fact/Answer sheet to them at that time.	
G. Circulate through class to monitor progress. Encourage discussion within work groups.	
IV. Trainees Work with Fact/Answer Sheet No. 2 (10 min.)	
A. After groups have had 10 minutes to work on Fact/Answer Sheet No. 1, distribute Fact/Answer Sheet No. 2.	*Instructor Notebook*, pages H3.1.2 and H3.1.5.
B. Groups working on problem No. 1 (odd numbered groups) work with page H3.1.2.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
C. Groups working on problem No. 2 (even numbered groups) work with page H3.1.5.	
D. Inform groups that in 10 minutes you will distribute the last part of the problem.	
E. Circulate through class and monitor work groups. As each group completes Fact/Answer Sheet No. 2, verify that they're on the right track and then distribute Fact/Answer Sheet No. 3. 1. Groups working on problem No. 1 should have identified the problem as hydraulic washout and the cause of the problem as inflow probably coming from basement sump pumps. 2. Groups working on problem No. 2 should have identified the problem as bulking caused by uncontrolled slug discharge of saline solution by the cannery. Provide assistance to groups as needed to help them identify the problem and its probable cause.	
V. Trainees Work with Fact/Answer Sheet No. 3 (10 min.)	
A. Distribute Fact/Answer Sheet No. 3 to work groups	*Instructor Notebook*, pages H3.1.3 and H3.1.6.
B. Groups working on problem No. 1 (odd numbered groups) work with page H3.1.3.	
C. Groups working on problem No. 2 (even numbered groups) work with page H3.1.6.	
D. Circulate through class to monitor activity.	
E. After 10 minutes call work to a halt.	

LESSON OUTLINE

VI. Discussion of Problem Number 1 (15 min.)

A. Work group reports, Fact/Answer Sheet Number 1.

1. Have one of the odd numbered work groups report their findings for Fact/Answer Sheet No. 1.
2. Encourage other groups to discuss the findings reported.
3. The following points should be included in the findings:

a. Who to talk to: Plant operators, street dept. supervisor, resident inspector during construction, water meter readers, municipal officials, any other possibly involved individuals

b. Information: collection system map, collection system construction specifications, any sewer use ordinances, construction inspector's diary, average water consumption information, rainfall data, flow records from plant, sewer maintenance records, complaints filed.

c. Records: construction records, plant flow records, complaint records, water consumption data.

d. Questions for operators:

(1) What does operator do to attempt to contain solids in plant?
(2) How soon after rainfall begins do flows increase?

KEY POINTS & INSTRUCTOR GUIDE

Key Point: Stress systematic approach.

Stress the need to talk to people and get needed information.

(3) How long after rainfall ceases do flows remain high?
(4) Does operator know of any possible sources of infiltration/inflow?

e. Visual observations;

(1) Determine if any inflow sources exist:

(a) Low lying manholes (vented)
(b) Yard or area drains
(c) Downspouts connected
(d) Catch basins connected
(e) Sump pumps in basements
(f) Sinkholes in areas where sewers were installed.

f. Other information:

(1) Actual construction practices (testimony)
(2) Results of any internal inspection or repair done since construction
(3) Records of any connections made since construction

B. Work Group Reports, Fact/Answer Sheet Number 2

1. Have another one of the odd numbered work groups report their findings for Fact/Answer Sheet No. 2.

2. Encourage other groups to discuss the findings reported.

3. The following points should be included in the findings:

a. The problem is hydraulic washout

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
of sludge caused by extraneous flow to plant generated by sump pumps installed in individual homes discharging ground water entering basements to the collection system.	Key Point: Analyze available information to determine possible causes of the problem.
b. Initial analysis of the flow data would indicate that the problem is one of infiltration since the flow characteristics of inflow are not apparent.	
c. Cause of problem:	
(1) Lack of adequate sewer use ordinances (2) Lack of proper inspection during construction	
C. Work Group Reports, Fact/Answer Sheet Number 3.	
1. Have another of the odd numbered work groups report their findings for Fact/Answer Sheet No. 3.	
2. Encourage other groups to discuss the findings reported.	
3. The following points should be included in the findings:	
a. Actions to take	Key Point: These actions can be taken immediately (1 month) to initiate removal of sump pumps.
(1) Immediate	
(a) Arrange to have house to house inspection performed to locate sump pumps. (b) Have sewer use ordinance passed which excludes sump pumps from legal connections.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
(c) Notify those individuals who have sump pumps that they must be disconnected from system.	
(2) Long Range	
(a) Follow-up on removal order for sump pumps. (b) Monitor plant flows to determine that they remain disconnected and that no new sources of extraneous flow occur.	
VII. Discussion of Problem Number 2 (15 min.)	
A. Work Group Reports, Fact/Answer Sheet No. 1	
1. Have one of the even numbered work groups report their findings for Fact/Answer Sheet No. 1.	
2. Encourage other groups to discuss the findings reported.	
3. The following points should be included in the findings:	
a. Who to talk to: plant operator, elected official responsible for the plant, cannery officials, state enforcement agency.	Stress the need to talk to people and to get needed information.
b. Information:	
(1) To what extent has effluent quality been impaired? (2) What is the settling quality of the sludge now and what was it before? (3) Was there a waste discharge by the cannery?	

LESSON OUTLINE | KEY POINTS & INSTRUCTOR GUIDE

(4) Is there a sample available of the industrial waste discharge?
(5) What are the regulations in the industrial waste ordinance?
(6) What was the characteristic of the industrial waste and how much was discharged?

c. Laboratory testing:

(1) Settling test 1 hr - mixed liquor
(2) pH - mixed liquor
(3) Suspended solids - effluent and mixed liquor
(4) BOD_5 - effluent
(5) pH - effluent
(6) D.O. - effluent and mixed liquor
(7) Total solids - effluent and mixed liquor

d. Visual observations:

(1) Is there a control structure for monitoring discharges from the cannery?
(2) What is the color and appearance, texture, etc. of the floc?

e. Other information:

(1) What are the different types of discharges that can be expected from the cannery?
(2) Who is the contact person at the cannery when problems occur?

B. Work Group Reports, Fact/Answer Sheet No. 2

LESSON OUTLINE | KEY POINTS & INSTRUCTOR GUIDE

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
1. Have another of the even numbered work groups report their findings for Fact/Answer Sheet No. 2.	
2. Encourage other groups to discuss the findings reported.	
3. The following points should be included in the findings:	
a. The problem appeared to have been a result of highly saline solution's effect on sludge microorganisms (1) Sludge lighter than liquid (liquid denser than usual) (2) Direction of osmosis impaired functioning or damage to cell structure of microorganism.	Key Point: Analyze available information to determine possible causes of the problem.
b. Cause of problem: (1) Saline solution entered plant in slug flow rather than fed slowly (2) Carelessness and ignorance on part of cannery personnel (3) Inadequacy of sewer ordinance to address industrial waste problems (4) Lack of communication between plant and cannery	Question for Class: What effect does the cannery's president being president of the town council have on your approach to this problem?
C. Work Group Reports, Fact/Answer Sheet Number 3	
1. Have another of the even numbered work groups report their findings for Fact/Answer Sheet No. 3.	
2. Encourage other groups to discuss the findings reported.	

LESSON OUTLINE

3. The following points should be included in the findings:

   a. Immediate Action

      (1) Waste sludge to empty aerator in an attempt to keep damaged microorganisms in plant and slowly bleed them back into flow scheme.
      (2) Attempt to maintain conditions for as rapid a growth as possible for new sludge.
      (3) Tell cannery to absolutely not discharge any more wastes until plant recovers.
      (4) Attempt to contain floating materials in polishing pond and recover.

   b. Long-term Action

      (1) Provide control sampling point for cannery discharge.
      (2) Revise ordinance to require pretreatment by cannery.
      (3) Provide that cannery must notify plant when discharging so plant has time to respond.
      (4) Provide samples of discharge for analysis.

   c. Evaluation Procedures:

      (1) Monitor cannery for discharges
      (2) Analyze discharges for:

         (a) Suspended solids
         (b) pH
         (c) Conductivity
         (d) BOD_5

      (3) Provide valve or other mechanism to prevent discharges from cannery if necessary

KEY POINTS & INSTRUCTOR GUIDE

Key Point: These actions can be taken immediately to initiate recovery of plant operation.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

VIII. Summarize Lesson

A. Must follow a systematic troubleshooting procedure.

   1. In both problems the problem was excess effluent suspended solids from a small activated sludge plant.

      a. One case was hydraulic washout caused by inflow.

      b. The second case was deflocculation caused by industrial shock load.

   2. By following the process of troubleshooting data were gathered and analyzed in a systematic way that led to identification of

      a. the problem, and
      b. the cause.

B. In both cases the problems were caused by inadequate management systems, i.e., inadequate sewer use control ordinances and the long term solutions were to correct the management deficiency.

C. These problems demonstrate that troubleshooting must be comprehensive and must consider the entire system - people and things.

D. These problems also show the importance of sewer use control in treatment facility operations and illustrate the effects of collection system deficiencies on treatment plant performance.

E. Distribute solutions to problems, pages H3.1.7 - H3.1.10.

F. Direct class to next agenda item.

Instructor Notebook pages H3.1.7 to H3.1.10 should be distributed to class to insert in the *Traine Notebook* for future reference.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 3: Sewer Use Control

Lesson 1: Applying the Process of Troubleshooting to Collection System Problems

Instructor Handout Contents

Problem No. 1, Fact/Answer Sheet No. 1 . . . . H3.1.1

Problem No. 1, Fact/Answer Sheet No. 2 . . . . H3.1.2

Problem No. 1, Fact/Answer Sheet No. 3 . . . . H3.1.3

Problem No. 2, Fact/Answer Sheet No. 1 . . . . H3.1.4

Problem No. 2, Fact/Answer Sheet No. 2 . . . . H3.1.5

Problem No. 2, Fact/Answer Sheet No. 3 . . . . H3.1.6

Solutions to Problems H3.1.7

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 3

Problem No. 1

Fact/Answer Sheet No. 1

GROUP # ____

PROBLEM: An operator you met recently at an operator's association meeting calls you by phone and asks for your technical assistance. The plant has a population equivalent of 500 people. He says that flows to the plant average about 45,000gpd. The operator says he sometimes has problems with the solids bulking out of his plant. He says that the problem usually occurs after a heavy rainfall.

On this answer sheet, list the actions you would take as a troubleshooter to assist in solving the problem. Please answer the following questions:

1. Who would you talk to about past performance of the system?
2. What information would you look for concerning design and construction of the system?
3. What records would you look at?
4. What questions would you ask about plant operations?
5. What visual observations would you make and what would you look for?
6. What other information, if any, would you need?

You have 10 minutes to complete this stage of the problem. When you complete this section, ask your instructor for Fact/Answer Sheet No. 2, page H3.1.2.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 3

Problem No. 1

Fact/Answer Sheet No. 2

GROUP # _____

During your investigation visit to the community you learn the following about the plant and collection system.

1. The plant meets NPDES requirements during dry weather.
2. Average design flow - 45,000 gpd.
3. Flow rate at time of visit: 120,000 gpd.
4. Rainfall - 4" during the three days preceeding your visit.
5. Plant is two-stage aeration modification of activated sludge.
6. Effluent suspended solids during visit: 200 mg/l.
7. Solids concentration in reaeration and aeration tank during visit: 900 mg/l.
8. Collection system was completed in 1968. Passed air pressure testing and exfiltration testing. Design with allowable infiltration of 250 gallons/in-diameter mile.
9. Visual inspection shows manholes in crown of road and tightly sealed.
10. Recent air testing of the system shows joints to be tight.
11. Water meter reader advises you that there might be sump pumps in basements connected to sewers.
12. Only existing ordinances are those which originally required connection.
13. A visual inspection shows that all roof leaders have been disconnected.

Using this data, please:

1. Identify and describe the nature of the problem.
2. Determine the likely causes of the problem.

You have 10 minutes to complete this stage of the problem.

CONSULT WITH THE INSTRUCTOR BEFORE CONTINUING. Request that the instructor give you Fact/Answer Sheet No. 3, page H3.1.3.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 3

Problem No. 1

Fact/Answer Sheet No. 3

GROUP #____

Now that you have identified the problem and its causes:

1. List the actions you would take to correct the problem.
    a. List alternative actions for immediate results.
    b. List long-range actions to prevent a recurrence.
2. What evaluation procedures would you use to monitor results of the corrective action?

You have 10 minutes to complete this stage of the problem.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 3

Problem No. 2

Fact/Answer Sheet No. 1

GROUP # _____

A small community has an 0.2 MGD design flow extended aeration activated sludge plant which is currently treating approximately 100,000 gpd. Information concerning the treatment units in the plant is as follows:

Unit	Number	Capacity
Aeration tanks*	2	100,000 gallons each
Aerobic digesters	2	100,000 gallons each
Secondary clarifiers*	2	25,000 gallons each
Chlorine contact tank	1	10,000 gallons
Effluent polishing pond	1	500,000 gallons

(*Only one tank in use)

Mechanical aeration is utilized in the plant. The sizing of the aerators is adequate for normal waste load.

There is one wet-industry in the community which is a large food processing canning concern. The process water from the cannery is seasonal with water consumption rates of around 100,000 gpd during the peak of the canning season. Normally the process water from the cannery is used for spray irrigation. However, when the spray irrigation system fails, cannery wastes are piped to the treatment plant. When the wastes are piped to the treatment plant, they are metered and the company operating the cannery pays according to a fee schedule per gallon for commercial users as stipulated in the sewer ordinance. The sewer ordinance is vague.

The operator at the plant calls you for assistance. He says the sludge floc will not settle in the plant. Solids are bulking out of the clarifier, through the chlorine contact tank to the effluent polishing pond.

What would you do as a troubleshooter? List the actions you would take in identifying and solving the problem.

1. What individuals would you contact about the problem?
2. What information would you seek? What questions would you ask? At the plant? At the cannery?
3. What visual observations would you make and what would you look for?
4. What laboratory testing would you perform?
5. What other information would you need?

You have 10 minutes to complete this stage of the problem. When you complege this section, ask your instructor for Fact/Answer Sheet No. 2, page H3.1.5.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 3

Problem No. 2

Fact/Answer Sheet No. 2

GROUP # _____

During your visit to the plant you learn the following:

1. Effluent suspended solid concentration is 300 mg/l, pH 7.2, D.O. 4.0 mg/l.
2. There are no requirements concerning the nature of industrial waste discharges in the sewer ordinance.
3. The pumps in the cannery's spray irrigation field failed earlier in the week and a tank of waste was diverted to the plant.
4. The volume of waste discharged to the plant was 20,000 gallons in a slug flow.
5. The slug of waste was a 2% saline solution used to separate young peas from old peas by flotation.
6. Maybe or maybe not, the spray irrigation was out of service since 2% solutions do not make good spray irrigates.
7. The cannery personnel do not appear to show any remorse about the plant conditions.
8. The settling test on the sludge show no settling over a one hour period.
9. No samples of the waste discharged are available at this time.
10. The president of the cannery is also president of the town council which is responsible for the waste treatment plant.

Using the information you have obtained during your visit to the plant and the cannery:

1. Identify and describe the nature of the problem.
2. Determine the likely causes of the problem.

You have 10 minutes to complete this stage of the problem.

CONSULT WITH THE INSTRUCTOR BEFORE CONTINUING. Request that the instructor give you Fact/Answer Sheet No. 3, page H3.1.6.

TROUBLESHOOTING O & M PROBLEMS IN
WASTEWATER TREATMENT FACILITIES

Unit of Instruction 3

Problem No. 2

Fact/Answer Sheet No. 3

GROUP # _____

Now that you have identified the problem and its causes:

1. List the actions you would take to correct the problem at the plant.
    a. List alternative actions for immediate results.
    b. List long-range actions to prevent a recurrence.
2. What evaluation procedures would you use to monitor results of the corrective action?

You have 10 minutes to complete this stage of the problem.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 3

SOLUTIONS TO PROBLEMS

Problem Number 1 - Sewer Use/Control

Fact/Answer Sheet No. 1

1. Who to talk to: Plant operators, street department supervisor, resident inspector during construction, water meter readers, municipal officials, any other possibly involved individuals.

2. Information: Collection system map, collection system construction specifications, any sewer use ordinances, construction inspector's diary, average water consumption information, rainfall data, flow records from plant, sewer maintenance records, complaints filed.

3. Records: Construction records, plant flow records, complaint records, water consumption data.

4. Questions for operators:

   a. What does operator do to attempt to contain solids in plant?
   b. How soon after rainfall begins do flows increase?
   c. How long after rainfall ceases do flows remain high?
   d. Does operator know of any possible sources of infiltration/inflow?

5. Visual observations: Determine if any inflow sources exist in:

   a. Low lying manholes (vented)
   b. Yard or area drains
   c. Downspouts connected
   d. Catch basins connected
   e. Sump pumps in basements
   f. Sinkholes in areas where sewers were installed

6. Other information:

   a. Actual construction practices (testimony)
   b. Results of any internal inspection or repair done since construction
   c. Records of any connections made since construction

Fact/Answer Sheet No. 2

1. The problem is hydraulic washout caused by extraneous flow to plant generated by sump pumps installed in individual homes discharging ground water entering basements to the collection systems.

2. Initial analysis of the flow data indicates that the problem may be one of infiltration because the flow characteristics of inflow are not apparent.

3. Cause of problem:

   a. Lack of sewer use ordinances
   b. Lack of proper inspection during construction

Fact/Answer Sheet No. 3

1. Actions to take:

   a. Immediate

      (1) Arrange to have house to house inspection performed to locate sump pumps

      (2) Have sewer use ordinance passed which excludes sump pumps from legal connections

      (3) Notify those individuals who have sump pumps that they must be disconnected from the system

   b. Long Range

      (1) Follow-up on removal order for sump pumps

      (2) Monitor plant flows to determine that they remain disconnected and that no new source of extraneous flow are occurring.

Problem Number 2 - Industrial Waste Monitoring

Fact/Answer Sheet No. 1

1. Who to talk to: Plant operator, elected official responsible for the plant, cannery officials, state enforcement agency.

2. Information:

   a. To what extent has effluent quality been impaired?
   b. What is the settling quality of the sludge now and what was it before?
   c. Was there a waste discharge by the cannery?
   d. Is there a sample available of the industrial waste discharge?
   e. What are the regulations in the industrial waste ordinance?
   f. What was the characteristics of the industrial waste and how much was discharged?

3. Laboratory testing:

   a. Settling test 1 hour - mixed liquor
   b. pH - mixed liquor
   c. Suspended solids - effluent and mixed liquor
   d. BOD_5 - effluent
   e. pH - effluent
   f. D.O. - effluent and mixed liquor
   g. Total solids - effluent and mixed liquor

4. Visual observations:

   a. Is there a control structure for monitoring discharges from the cannery?
   b. What is the color and appearance, texture, etc. of the floc?

5. Other informantion:

   a. What are the different types of discharges that can be expected from the cannery?
   b. Who is the contact person at the cannery when problems occur?

Fact/Answer Sheet No. 2

1. The problem appeared to have been a result of highly saline solution's effect on sludge microorganisms

   a. Sludge lighter than liquid (liquid denser than usual)
   b. Direction of osmosis impaired functioning or damage cell structure of microorganism

2. Cause of the problem:

   a. Saline solution entered plant in slug flow rather than fed slowly

b. Carelessness and ignorance on part of cannery personnel
c. Inadequacy of sewer ordinance to address industrial waste problems
d. Lack of communication between plant and cannery

Fact/Answer Sheet No. 3

1. Immediate action

   a. Waste sludge to empty aerator in an attempt to keep damaged microorganisms in plant and slowly bleed them back into flow scheme
   b. Attempt to maintain conditions for as rapid a growth as possible for new sludge
   c. Tell cannery to absolutely not discharge any wastes until plant recovers
   d. Attempt to contain floating materials in polishing pond and recover

2. Long-term Action

   a. Provide control sampling point for cannery discharge
   b. Revise ordinance to require pre-treatment by cannery
   c. Provide that cannery must notify plant when discharging and limit rate of discharge so plant has time to respond
   d. Provide samples of discharge for analysis

3. Evaluation Procedures

   a. Monitor cannery for discharges
   b. Analyze discharges for

      (1) Suspended solids
      (2) pH
      (3) Conductivity
      (4) BOD_5

   c. Provide valve or other mechanism to prevent discharges from cannery if necessary

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 3: Sewer Use Control

Lesson 2: Sewer Use Control and Industrial Waste Monitoring

Lesson 2 of 2 Recommended Time: 45 minutes

Purpose: The lesson outlines some of the wastewater treatment facility performance problems which may be caused by collection system deficiencies, reviews the impact of industrial waste on treatment operations, summarizes federal regulations on industrial pretreatment and monitoring requirements and identifies desirable features for a local sewer use control ordinance. The above are applied to identify procedures which can be used to assist municipalities in preparing, using and enforcing sewer use control ordinances and industrial waste monitoring and pretreatment programs.

Trainee Entry Level Behavior: Trainees will have completed Unit 1, *Overview*, and Unit 2, *Elements of Troubleshooting*, before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. List, from memory, at least five collection system deficiencies which can cause wastewater treatment facility performance upsets, explain how each may affect the treatment process, describe how each collection system deficiency can be identified and list alternative corrective actions for each collection system deficiency.

2. List, using references and class notes, at least three criteria which can be used to measure the effectiveness of collection system operation and maintenance.

3. From memory, name at least one training program which is available to collection system O & M personnel to upgrade their skills.

4. Using references and class notes, list the principal provisions of the Federal regulations on industrial waste pretreatment and monitoring.

5. List and describe, using references and class notes, the steps in organizing and conducting an industrial waste survey.

6. Using references and class notes, list and describe the major provisions which should be included in a local sewer use control ordinance, explain the importance of each to monitoring and control of sewer use and explain how the sewer use control ordinance can be used to improve the performance of wastewater treatment facilities.

7. Using references and class notes, explain how you can assist a municipality in preparing, using and enforcing a sewer use control ordinance and industrial waste pretreatment and monitoring programs.

Instructional Approach: Illustrated lecture and class discussion.

Lesson Schedule: The 45 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 5 minutes	Collection System Effects on Treatment
5 - 15 minutes	Evaluating Collection System O & M
15 - 25 minutes	Industrial Pretreatment and Monitoring
25 - 35 minutes	The Industrial Waste Survey
35 - 45 minutes	The Sewer Use Control Ordinance

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T3.2.1 - T3.2.4, "Collection System Conditions Affecting Treatment Operations."

2. *Trainee Notebook*, pages T3.2.5 - T3.2.11 , "EPA's New Pretreatment Program."

3. *Trainee Notebook*, pages T3.2.12 - T3.2.18 , "The Impact of Toxic Pollutants on Disposal from Wastewater Systems."

4. *Trainee Notebook*, pages T3.2.19 - T3.2.21 , "Example Industrial Waste Survey Form."

5. *Trainee Notebook*, pages T3.2.22 - T3.2.27 , "Example Sewer Use Control Ordinance."

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 3, Lesson 2, pages 3.2.1 - 3.2.23.
2. Slides 179.2/3.2.1 - 179.2/3.2.13.

Instructor Materials Recommended for Development:

1. Incorporate state or local implementing regulations on industrial waste pretreatment and monitoring if they are available.
2. Use your state's "model sewer use control ordinance" to replace the example in the *Trainee Notebook*, pages T3.2.22 - T3.2.27.

Additional Instructor References:

1. Seminar on Pretreatment of Industrial Waste, Environmental Protection Agency, Technology Transfer, Cincinnati, OH (1978).
    a. Biener, J.A. and Bouma, W.H., "Case History: City of Grand Rapids, Michigan Program of Industrial Waste Control."
    b. Dyer, J.C., "Local Pretreatment Program Requirements."
    c. Schwartz, H. G., Jr. and Buzzell, J.C., Jr., "The Impact of Toxic Pollutants on Municipal Wastewater Systems."
    d. Steffen, A. J., "Effects and Removability of Industrial Pollutants."
    e. Vernick, A. S., Feiler, H. D., Lanik, P. D., "Elements of an Industrial Waste Control Program."
2. Environmental Protection Agency Pretreatment Standards, 43, Federal Register, 27746 (June 26, 1978).
3. Brody, J. et al, "Performance Indicators for Wastewater Collection Systems," Journal Water Pollution Control Federation, 51, pp. 695-708 (1979).

4. Kerri, K. and Brady, J., Operation and Maintenance of Wastewater Collection Systems, Training Manual, University of California at Sacramento, Sacramento, CA (1976).

5. Process Design Manual for Sulfide Control in Sanitary Sewer Systems, Technology Transfer, Environmental Protection Agency, Cincinnati, OH (1974).

6. Industrial Waste Monitoring, Technology Transfer, Environmental Protection Agency, Cincinnati, OH (1974).

7. Regulation of Sewer Use, MOP 3, Water Pollution Control Federation, Washington, D.C.

8. Sewer Maintenance, MOP 7, Water Pollution Control Federation, Washington, D.C.

9. Design and Construction of Sanitary and Storm Sewers, MOP 9, Water Pollution Control Federation, Washington, D.C.

10. Handbook for the Evaluation and Rehabilitation of Wastewater Collection Systems, Environmental Protection Agency, Washington, D.C. (1976).

11. Schwartz, H. G. and Buzzell, J. C., "The Impact of Toxic Pollutants on Disposal from Wastewater Systems," Industrial Water Engineering, pp. 14-20, October-November, 1978.

12. Hall, R. M., "EPA's New Pretreatment Program," Industrial Water Engineering, pp. 8-14, September, 1978.

Classroom Set-Up: As specified in Unit 3, Lesson 1.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	Note to Instructor: All slides in this lesson are available as print masters which may be used to make overhead transparencies.
I. Collection System Effects on Treatment (5 min.)	Use Slide 179.2/3.2.1 Slide 179.2/3.2.1 is a blank used to blacken screen.
A. Discuss the importance of sewer use control on treatment operations.	
1. Refer to problems solved in Unit 3, Lesson 1 as examples of improper sewer use control and its effect on treatment operations.	
a. Inflow caused hydraulic overload and solids washout at treatment plant.	Refer to Problem No. 1, Unit 3, lesson 1.
b. Toxic waste discharge as a shock load completely disrupted biological treatment.	Refer to Problem No. 2, Unit 3, lesson 1.
2. Note that many plant operational problems manifest themselves as excess effluent BOD or TSS. In many cases the cause and correction of the operational problem lies in correcting defects in collection system O & M or in sewer use control.	
B. Emphasize the systematic nature of troubleshooting.	
1. Must consider complete system in evaluation:	
a. Receiving stream	
b. Treatment plant	

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

c. Collection system

d. Management

2. Too often troubleshooters focus on the treatment plant and forget the other components in the system.

3. Proper application of the *Process of Troubleshooting* will direct attention to the real causes of problems when all alternatives are considered and then systematically prioritized.

Refer class to *Trainee Notebook*, page T2.2.8, "The Process of Troubleshooting."

C. Lesson Outline and Objectives

1. The lesson on sewer use control will present the following topics:

    a. Evaluating Collection System O & M

    b. Industrial Pretreatment and Monitoring

    c. Industrial Waste Survey

    d. Sewer Use Control Ordinance

2. The principal objectives of the lesson are to help you develop skills to:

    a. Evaluate the collection system as a potential source of problems.

    b. Assist municipalities prepare and enforce sewer use control, industrial waste pretreatment and industrial waste monitoring programs.

II. Evaluating Collection System O & M (10 min.)

A. Identify collection system deficiencies which could adversely affect treatment plant performance.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
1. Select one trainee to be the class recorder and ask him/her to list potential problems on the chalkboard as they are identified.	
2. Ask class to give examples of collection system deficiencies and problems which could cause treatment problems.	Encourage class participation
3. For each deficiency or problem listed have class discuss the following aspects of troubleshooting the problem or deficiency: a. Possible causes b. How the problem's cause could be identified c. The effect on treatment plant operations d. Corrective actions which might be taken	
B. The following lists the more common collection system problems or deficiencies which should be identified by the class: 1. Sewer clogging and overflow 2. Excessive grit entering the system 3. Excessive organic loading 4. Excessive hydraulic loading a. Inflow (surface water) b. Infiltration (ground water) c. Improper lift station operation 5. Industrial wastes	

LESSON OUTLINE

   a. Toxic materials

   b. Excessive organic loads

   c. Excessive hydraulic loads

C. During discussion of these problems, the following should be covered:

1. Sewer Clogging

   a. Cause:

      (1) Improper design
      (2) Inadequate collection system maintenance

   b. Effect:

      (1) Sewage overflows (health hazard)
      (2) Shock load to plant
      (3) Shock hydraulic load to plant
      (4) Septic conditions in sewer

   c. Remedy:

      (1) Correct design problem
      (2) Implement planned preventive maintenance program

2. Excessive Grit Materials

   a. Cause:

      (1) Combined collection system
      (2) Inadequate street, storm inlet or catch basin cleaning programs
      (3) Improperly maintained regulation station allows grit to enter plant during wet weather flows

KEY POINTS & INSTRUCTOR GUIDE

This information is included in the *Trainee Notebook* as pages T3.2.1 - T3.2.4, "Collection System Conditions Affecting Treatment Plant Operations."

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

b. Effect:

(1) Excessive wear on plant equipment
(2) Grit takes up valuable detention volume in tanks
(3) Excessive solids handling in grit removal

c. Remedy:

(1) Improve or initiate storm inlet/catch basin cleaning program
(2) Repair or readjust regulator stations

3. Excessive Organic Loadings

a. Cause:

(1) Industrial wastes
(2) Improper lift station operation

b. Effect:

(1) Organic overload with plant unable to meet NPDES BOD_5 and TSS requirements
(2) Excessive biological solids production and handling in plant
(3) Possible nutrient deficiencies
(4) Oxygen transfer limitations

c. Remedy:

(1) Institute and enforce industrial waste ordinance
(2) Perform surveillance to locate source of waste
(3) Work with industry to provide for adequate pretreatment of waste

- (4) Check and adjust lift station operations

4. Excessive Hydraulic Loadings

   a. Cause:

      (1) Surface water - inflow
         (a) Downspouts
         (b) Foundation drains
         (c) Improperly located or poorly maintained clean-out vents
         (d) Yard drains
         (e) Improperly located and sealed manhole covers
         (f) Basement sump pumps

      (2) Ground water - infiltration
         (a) Damaged pipe
         (b) Leaking manhole barrel
         (c) Improperly sealed joint

      (3) Industrial waste discharges
      (4) Improper lift station operation

   b. Effect:

      (1) Detention time in treatment units reduced during high flows
      (2) Organic solids washed out in treatment plant effluent with failure to meet BOD_5 and suspended solids NPDES requirements
      (3) Surge loads to plant

   c. Remedy:

      (1) Perform infiltration/inflow detention survey
      (2) Seal sources of inflow where cost effective

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

(3) Rehabilitate or replace faulty pipes and manholes where cost effective

(4) Prepare and enforce specifications and construction practices by ordinance (develop specifications)

(5) Pressure test new lines before acceptance

(6) Enforce industrial waste control ordinances

(7) Check and adjust lift station operations

5. Toxic Materials

a. Cause:

(1) Industrial wastes

b. Effect:

(1) Inhibit biological system causing excess effluent COD and TSS

(2) Pass through treatment plant

(3) Accumulation in treatment plant sludges

c. Remedy:

(1) Prepare and enforce an effective sewer use control ordinance

(2) Institute effective industrial waste monitoring program

(3) Enforce industrial pretreatment requirements

D. Refer class to *Trainee Notebook*, pages T3.2.1 - T3.2.4, "Collection System Conditions Affecting Treatment Plant Operations."

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

E. Criteria for Evaluating Effectiveness of Collection System O & M

1. Troubleshooter often needs to evaluate the adequacy of collection system operation and maintenance. If collection system operation and maintenance is satisfactory, the troubleshooter may be able to eliminate the collection system as a major source of treatment plant operational problems.

2. Data to be reviewed include:

   a. Collection system maintenance

      (1) Sewer line maintenance
         (a) Sewer lines cleaned (miles/year)
         (b) Stoppages cleared (number/year)
         (c) Citizen complaints
            1. Flooding (number/year)
            2. Odors (number/year)
      (2) House Services
         (a) New taps made and services installed (number/year)
         (b) Stoppages cleared (number/year)
         (c) Inspections for illegal connections (number/year)

   b. Lift station operation and maintenance

      (1) Number of lift stations
      (2) Amount of wastewater pumped (MG/year)
      (3) Inspections and services of lift stations
         (a) Scheduled (frequency)
         (b) Unscheduled (number/year)

   c. Industrial waste surveillance

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
(1) Inventory of industrial discharges (2) Frequency of sampling (3) Frequency of inspection of pretreatment systems (4) Violations of sewer use control ordinance (a) Severity of violation (number per year and duration) (b) "Enforcement actions" (number/year)	
3. Evaluation of data:	
a. Sewer maintenance data	Expect few treatment problems caused by inadequate sewer maintenance.
(1) Desired finding: sewers inspected and cleaned on regular schedule, few stoppages and few complaints.	
(2) Negative finding: little or no regularly scheduled maintenance and inspection, many stoppages and complaints.	Expect some treatment problems from slug organic and hydraulic loads and possibly septic sewage.
b. Lift station O & M	
(1) Desired finding: Frequent scheduled inspection and service; few unscheduled inspection and service calls.	Expect few treatment problems caused by lift stations.
(2) Negative finding: No routine inspection and service; frequent stoppage with repair service calls.	Expect some treatment problems from surge flows; possibly frequent flooding and overflows.
c. Industrial waste monitoring	
(1) Desired finding: Up-to-date inventory; good sewer use ordinance; regular sampling	Expect few treatment problems caused by industrial wastes. At least, you'll know what's in

LESSON OUTLINE

and inspection of pretreatment facilities with enforcement as needed.

(2) Negative finding: No inventory; poor sewer use ordinance; limited surveillance; no enforcement

4. Refer class to "Collection System Operation and Maintenance," a self-study training manual available from University of California at Sacramento, Sacramento, California, as excellent source document on collection system O & M. Highly recommended to aid in upgrading skills of personnel responsible for the collection system.

III. Industrial Pretreatment and Monitoring

A. Inform class that several Federal laws address control of industrial wastes. Federal legislation with impact on industrial waste control includes:

1. PL 92-500 and PL 95-217, the Federal Water Pollution Control Act and the Clean Water Act of 1977 require EPA to set industrial pretreatment standards.

2. TOSCA, the Toxic Substances Control Act of 1977, requires regulations to limit discharge of toxic substances.

3. RCRA, the Resource Conservation and Recovery Act of 1977, places limits on disposal of toxic and hazardous materials.

B. Under PL 92-500 and PL 95-217 EPA issued general Pretreatment Regulations on June 26, 1978.

KEY POINTS & INSTRUCTOR GUIDE

the system and what to look for if you suspect industrial waste problems.

If plant evaluation indicates potential industrial waste problem, you'll have to start from scratch to find who, what, where and when.

Refer to *Trainee Notebook*, pages T3.2.5 - T3.2.11 for a summary of EPA Pretreatment Regulations.

LESSON OUTLINE

1. *Trainee Notebook* pages T3.2.5-T3.2.11 summarizes major provisions of these regulations

2. Purposes of Pretreatment

   a. Use Slide 179.2/3.2.2 to review purposes of pretreatment.

   b. Note that these are criteria EPA used in promulgating pretreatment standards

3. National Pretreatment Standards

   a. Two groups:

      (1) Prohibited discharges
      (2) Categorical standards

   b. Prohibited Discharges

      Use Slide 179.2/3.2.3 to illustrate the following prohibited discharges

      (1) Pollutants that create a fire or explosive hazard.
      (2) Pollutants causing corrosive damage to publicly owned treatment works, discharges with pH values below 5.0.
      (3) Solid or viscous pollutants in amounts that could cause obstructions in sewers or otherwise interfere with operation of the publicly owned treatment works.
      (4) Slug discharges, in terms of volumes, strength or oxygen

KEY POINTS &
INSTRUCTOR GUIDE

Dim Lights

Use Slide 179.2/3.2.2

Slide 179.2/3.2.2 reads:

"Purposes of Pretreatment

* Protect publicly owned treatment works
  * Continuity of Treatment
  * Physical Protection
* Prevent Pass-through
  * Satisfy NPDES Permit
  * Protect receiving waters"

Use Slide 179.2/3.2.3

Slide 179.2/3.2.3 reads:

"Prohibited Discharges

* Fire or Explosive Hazard
* Corrosive Damage
* Sewer Obstructions
* Slug Discharges
* Heat"

LESSON OUTLINE

demand, of such magnitude to cause treatment process upsets and loss of treatment efficiency.

(5) Heat in amounts that will inhibit biological activity at the publicly owned treatment works, specifically discharges that cause the temperature at the publicly owned treatment works influent to exceed 40°C (104°F).

4. Categorical Standards

Use Slide 179.2/3.2.4 to illustrate categorical standards:

a. Preclude discharge of pollutants are incompatible with publicly owned treatment works, i.e., those pollutants which the publicly owned treatment works was not designed to remove. Under the definition, excessively high BOD or TSS could be classed as incompatible.

b. Standards required for 21 industrial classifications.

c. Standards required for 65 classes of toxic pollutants (129 chemical compounds or elements). See *Trainee Notebook*, page T3.2.5 for listing of 65 classes.

d. All standards are to be technology based to reflect best available treatment technology.

C. Effects of Industrial Wastes on Treatment Operations

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/3.2.4

Slide 179.2/3.2.4 reads:

"Categorical Standards

* Incompatible Pollutants
* 21 Industrial Categories
* 65 Classes of Toxic Pollutants
* Technology Based Standards"

Use Slide 179.2/3.2.5

Slide 179.2/3.2.5 reads:

LESSON OUTLINE

Use slide 179.2/3.2.5 to illustrate

1. Interference with publicly owned treatment works. Examples:
   a. Overloading
      (1) Organic
      (2) Hydraulic
   b. Toxicity or inhibition of biological activity
      (1) Extreme pH
      (2) High temperatures
      (3) Toxic substances
         (a) Heavy metals
         (b) Organics
   c. Corrosion
   d. Slowly metabolized substances
2. Sludge contamination

   Sludges accumulate some toxic materials, e.g. heavy metals, which can restrict options for sludge handling and disposal or result in a cummulative toxic effect.
3. Pass-through and discharge at unacceptable levels.

   Many substances pass-through publicly owned treatment works with minimal removals. Examples:
   a. Dissolved inorganic solids
   b. Slowly metabolized organics
   c. Metals

KEY POINTS & INSTRUCTOR GUIDE

"Problems with Industrial Waste

1. Interference with treatment
2. Sludge contamination
3. Pass-through"

LESSON OUTLINE

4. Refer class to *Trainee Notebook*, pages T3.2.12 - T3.2.18, for detailed discussion of the effects of industrial wastes on publicly owned treatment works.

D. PL 95-217 and pretreatment regulations delegate primary enforcement of pretreatment standards to local pollution control agencies.

   1. Mandatory pretreatment program if the local pollution control agency operates facilities with total design flow greater than 5.0 MGD.

   2. May be required of smaller agencies at option of EPA Region or State agency.

   3. Local pretreatment program must include the following elements:

      a. Enforceable legal authority which includes authority to monitor, sample and inspect industrial pretreatment facilities, authority to require self-monitoring, authority to enforce pretreatment standards and authority for imposing penalties.

      b. Authority to identify and inventory all industrial waste discharges.

      c. Adequate funding and personnel to conduct the program.

   4. All the above translate to a potential need to provide increased assistance to publicly owned treatment works in establishing and implementing industrial pretreatment programs. It provides a legal basis to remedy problems caused by industrial waste discharges.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/3.2.6

Slide 179.2/3.2.6 reads:

"Enforcement of Pretreatment Standards

- Local Pollution Control Agency Operates Facilities
- Pretreatment Program Elements
  - Enforceable Legal Authority
    Monitoring
    Reporting
    Inspections
    Penalties
  - Inventory Authority
  - Resources"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
5. The next two sections address the inventory and legal authority elements of the local pretreatment program.	
IV. The Industrial Waste Survey (10 min.)	
A. Steps in establishing an inventory of industrial discharges	Use Slide 179.2/3.2.7 Slide 179.2/3.2.7 reads:
1. Develop listing of all potential sources of industrial wastes	"Industrial Discharge Data Base
2. Review listing to identify most likely candidates for detailed study	* List of Potential Dischargers * Preliminary Analysis of Data * Questionnaire Survey * Detailed Data Analysis * Sampling Programs"
3. Develop survey questionnaire and conduct the survey	
4. Analyze survey data	
5. Conduct sampling programs if needed	
B. Develop listing of potential dischargers (sources of information)	Use Slide 179.2/3.2.8 Slide 179.2/3.2.8 reads:
1. Use Slide 179.2/3.2.8 to list sources of information to identify potential dischargers.	"Identifying Potential Dischargers
2. Let trainees review slide and answer questions about any item listed.	* Sewer Authority Files * City and State Industrial Records * Property Tax Records * Chamber of Commerce * Telephone Directory * Water Department Records * Dun's Market Identifiers (Dun and Bradstreet)"
C. Preliminary data acquisition	
Use Slide 179.2/3.2.9 to summarize data to be gathered about each potential discharger	Use Slide 179.2/3.2.9 Slide 179.2/3.2.9 reads:

LESSON OUTLINE

1. Location - mailing address, office address, potential discharge point(s).
2. SIC Classification - EPA is issuing categorical pretreatment standards by SIC Classification.
3. What is produced and how large is the operation?

D. Analysis of preliminary data

1. Group master list by SIC classification.
2. Determine which industries you expect to discharge to the system and estimate the quantity of discharge to identify those which would be significant dischargers (greater than 25,000 gpd).
3. Based on SIC classification determine which dischargers would likely have a significant impact on the treatment plant.
4. Use the above data analysis to guide your preparation of instruments to gather more detailed data.

E. The survey questionnaire

1. Questionnaire format and detail will depend on size of the system and the number of discharges:
   a. Small system - interview.
   b. Larger system - mail questionnaire designed for use with data processing system.
2. Information needed includes:

KEY POINTS & INSTRUCTOR GUIDE

"Preliminary Data on Industries

- * Location
- * SIC Classification
- * Product Line
- * Production Volume"

Use Slide 179.2/3.2.10

Slide 179.2/3.2.10 reads:

"Preliminary Data Analysis

- * Master List
- * Group by SIC
- * Wet or Dry?
- * Significant Discharger?
- * POTW Sensitivity to Waste"

Use Slide 179.2/3.2.11

Slide 179.2/3.2.11 reads:

"Survey Questionnaire Data"

- * Who
- * Production
- * Employment
- * Water Use
- * Sewer Connections
- * Discharge Characteristics"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
a. Respondent identification and who is responsible for wastewater, i.e., who can give more information if it is needed.	
b. Production - what and how much?	
c. Employment - number	
d. Water usage data	
e. Number and location of sewer connections	
f. Characteristics of the waste discharges (1) Volume (2) Pollutants (3) Batch or Continuous?	
3. Refer class to *Trainee Notebook*, pages T3.2.19 - T3.2.21, "Example Industrial Waste Survey."	
4. Survey procedures	
a. Precede mailing with public relations program - let industry know what's coming and why. (1) Letters to industry (2) Media so public knows	
b. Mail survey form to master list of industries	
c. Follow-up mailing if needed.	
d. Telephone follow-up to get response.	
e. If necessary, plant visit and interview.	

5. Analyze data to identify:

   a. Pollutants subject to Federal pretreatment standards.

   b. Pollutants which would pass-through treatment system.

   c. Compatibility with NPDES permit requirements.

   d. Special treatment requirements to meet water quality standards.

   e. Pollutants which would interfer — with treatment plant.

6. With above data in hand, you're ready to write the sewer use control ordinance.

V. Sewer Use Control Ordinance

A. Refer class to *Trainee Notebook*, pages T3.2.22 - T3.2.27, "Example Sewer Use Control Ordinance."

B. Use Slide 179.2/3.2.12 and review essential provisions of sewer use control ordinances.

   1. State area of jurisdiction and who has responsibility.

   2. Explicit definitions of all terms used in ordinance.

   3. List all prohibited discharges.

   4. List limitations on specific pollutants, both quantity and concentration as appropriate.

   5. Establish responsibilities for control

Use Slide 179.2/3.2.12

Slide 179.2/3.2.12 reads:

"Ordinance Provisions

- Area of Jurisdiction
- Definitions
- Prohibited Materials
- Specific Pollutants
- Authority and Procedures for Control
- Monitoring and Reporting
- Enforcement Procedures
- Procedural Clauses with Dates
- Severability Clause"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
between discharger and treatment works with schedules as appropriate.	
6. State monitoring and reporting requirements with authority of access, inspection and sampling.	
7. Define enforcement procedures, penalties and appeals procedures.	
8. Include procedural clauses with effective dates.	
9. Include severability clause.	
C. Serve primarily as a technical resource person - make sure that the treatment authority's attorneys handle legal aspects.	
VI. Discussion	Use Slide 179.2/3.2.13 Slide 179.2/3.2.13 is a blank slide used to blacken screen. Turn Lights Up
A. Encourage discussion and questions in any remaining time.	
B. Direct class to next agenda item.	

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 3: Sewer Use Control

Lesson 2: Sewer Use Control and Industrial Waste Monitoring

Trainee Notebook Contents

Collection System Conditions Affecting Treatment Conditions T3.2.1

Article, "An Attorney Reviews EPA's New Pretreatment Program," by Ridgway M. Hall, Jr. T3.2.5

Article, "The Impact of Toxic Pollutants on Disposal from Wastewater Systems," by Henry G. Schwartz, Jr. and James C. Buzzell, Jr. T3.2.12

Example Industrial Waste Survey Form T3.2.19

Example Sewer Use Ordinance T3.2.22

References T3.2.28

Collection System Conditions Affecting Treatment Operations

A. Sewer Clogging

1. Cause:
    - a. Improper design
    - b. Inadequate Collection system maintenance
2. Effect:
    - a. Sewage overflows (health hazard)
    - b. Shock load to plant
    - c. Shock hydraulic load to plant
    - d. Septic conditions in sewer
3. Remedy:
    - a. Correct design problem
    - b. Implement planned preventive maintenance program

B. Excessive Grit Materials

1. Cause:
    - a. Combined collection system
    - b. Inadequate street, storm inlet or catch basin cleaning programs
    - c. Improperly maintained regulation station allows grit to enter plant during wet weather flows
2. Effect:
    - a. Excessive wear on plant equipment
    - b. Grit takes up valuable detention volume in tanks
    - c. Excessive solids handling in grit removal

3. Remedy:

   a. Improve or initiate storm inlet/catch basin cleaning program

   b. Repair or readjust regulator stations

C. Excessive Organic Loadings

1. Cause:

   a. Industrial wastes

   b. Improper lift station operation

2. Effect:

   a. Organic overload with plant unable to meet NPDES BOD_5 and TSS requirements

   b. Excessive biological solids production and handling in plant

   c. Possible nutrient deficiencies

   d. Oxygen transfer limitations

3. Remedy:

   a. Institute and enforce industrial waste ordinance

   b. Perform surveillance to locate source of waste

   c. Work with industry to provide for adequate pretreatment of waste

   d. Check and adjust lift station operations

D. Excessive Hydraulic Loadings

1. Cause

   a. Surface water - inflow

        (1) Downspouts
        (2) Foundation drains
        (3) Improperly located or poorly maintained cleanout vents
        (4) Yard drains
        (5) Improperly located and sealed manhole covers
        (6) Basement sump pumps

    b. Ground water - infiltration

        (1) Damaged pipe
        (2) Leaking manhole barrel
        (3) Improperly sealed joint

    c. Industrial waste discharges

    d. Improper lift station operation

2. Effect:

    a. Detention time in treatment units reduced during high flows

    b. Organic solids washed out in treatment plant effluent with failure to meet BOD_5 and suspended solids NPDES requirements

    c. Surge loads to plant

3. Remedy:

    a. Perform infiltration/inflow detention survey

    b. Seal sources of inflow where cost effective

    c. Rehabilitate or replace faulty pipes and manholes where cost effective

    d. Prepare and enforce specifications and construction practices by ordinance (develop specifications)

    e. Pressure test new lines before acceptance

    f. Enforce industrial waste control ordinances

    g. Check and adjust lift station operations

E. Toxic Materials

1. Cause:
    a. Industrial wastes
2. Effect:
    a. Inhibit biological system causing excess effluent COD and TSS
    b. Pass through treatment plant
    c. Accumulation in treatment plant sludges
3. Remedy:
    a. Prepare and enforce an effective sewer use control ordinance
    b. Institute effective industrial waste monitoring program
    c. Enforce industrial pretreatment requirements

T3.2.5 - T3.2.18 "AN ATTORNEY REVIEWS EPA'S NEW PRETREATMENT PROGRAM" AND "THE IMPACT OF TOXIC POLLUTANTS ON DISPOSAL FROM WASTEWATER SYSTEMS" REMOVED DUE TO COPYRIGHT RESTRICTIONS.

EXAMPLE INDUSTRIAL WASTE SURVEY FORM

SIC # ____________
MAP # ____________
LOC # ____________
S.D. ____________
(For BSA use only)

BUFFALO SEWER AUTHORITY
INDUSTRIAL WASTE SURVEY
SHEET 1 of 3

COMPANY NAME: ______________________________________

ADDRESS: ______________________________________

REPRESENTATIVE ______________ TITLE ____________ PHONE. NO. ________

HOURS OF OPERATION/DAY ____________ DAYS OF OPERATION/WEEK ____________

NO. OF EMPLOYEES: SHIFT NO. 1 ______ SHIFT NO. 2 ______ SHIFT NO. 3 ______

TYPE OF BUSINESS: (MANUFACTURER, DISTRIBUTOR OR RETAIL) ____________

RAW MATERIALS	AMOUNT PER YEAR

PRODUCTS	AMOUNT PER YEAR

TYPE OF PROCESS: CONTINUOUS ____________ BATCH ____________

INDUSTRIAL WASTES:

WHAT WASTE PRODUCTS ARE DISPOSED TO: SEWER ____________ OTHER: ________

IS DISCHARGE TO SEWER: INTERMITTENT __________ STEADY __________

QUANTITY/DAY __________ EST. OR MEASURED __________

ARE WASTES PRETREATED? IF SO, WHICH AND HOW: ____________________

BUFFALO SEWER AUTHORITY
INDUSTRIAL WASTE SURVEY

SHEET 2 of 3

PLANT SEWER CONNECTIONS TO BSA

	SIZE & SHAPE	MATERIAL	LOCATION IN PLANT	CONNECTED TO
(1)				
(2)				
(3)				

ARE MAPS SHOWING SEWER CONNECTIONS AVAILABLE? ______

ADDITIONAL INFORMATION TO BE SUPPLIED ON YOUR LETTERHEAD.

ANNUAL VARIATION IN OPERATION

IS THERE A SCHEDULED SHUTDOWN? ______ WHEN? ______

IS PRODUCTION SEASONAL? ______

IF SO: PERIOD OF FULL PRODUCTION ______ TO ______

PERIOD OF LIMITED PRODUCTION ______ TO ______

PERIOD OF NO PRODUCTION ______ TO ______

EMPLOYEES (NO.) MAX. ______ % OF TIME AT MAX. ______

MIN. ______ % OF TIME AT MIN. ______

IF NOT: AVERAGE # OF EMPLOYEES: ______

WATER USE

SOURCE(S) OF WATER ______

IF FROM AN AGENCY, ACCOUNT # ______

BUFFALO SEWER AUTHORITY
INDUSTRIAL WASTE SURVEY

SHEET 3 of 3

WATER USED FOR:			RECIRCULATED
SANITARY	____________	GPD	____________
AIR CONDITIONING	____________	GPD	____________
PROCESS WATER	____________	GPD	____________
JACKETED COOLING WATER	____________	GPD	____________

OTHER ______________________________

PERIOD OF MAX. WATER USE ____________ AMOUNT ____________

PERIOD OF MIN. WATER USE ____________ AMOUNT ____________

WATER DISPOSAL OTHER THAN SEWER ____________ % OF TOTAL ____________

IS WATER CONSUMED IN PRODUCT? ____________ AMOUNT/DAY ____________

TYPE AND NUMBER OF AIR POLLUTION DEVICES ____________________

HAVE THE WASTE STREAMS BEEN PREVIOUSLY ANALYZED? ____________________

ARE RADIOACTIVE ISOTOPES USED IN YOUR PROCESS? ______ SPECIFY: ________

EXAMPLE SEWER USE ORDINANCE

(from Grand Rapids, Michigan)

"2.63. Management of the Sewage Disposal System. The Grand Rapids Sewage Disposal System shall be and remain under the management, supervision, and control of the City Manager who may employ or designate such person or persons in such capacity or capacities as he deems advisable to carry out the efficient management and operation of the System. The City Manager or his designee may make such rules, orders or regulations as he deems advisable and necessary to assure the efficient management and operation of the System; subject, however, to the rights, powers and duties with respect thereto which are reserved by law to the City Commission of Grand Rapids.

"2.64. Standards, Rules and Regulations. The standards, rules and regulations established in or pursuant to this chapter are deemed to be the absolute minimum consistent with the preservation of the public health, safety and welfare, to prevent pollution of the environment, and to fulfill the obligations of the City with respect to State and Federal law and all rules and regulations adopted in conformance thereto. The discharge into the System of any substance which exceeds the limitations contained herein, or in any manner fails to conform hereto, is hereby declared to be a public nuisance, and a violation of this Code.

"2.65. Use of the Sewage Disposal System. Any person conforming to the standards, rules and regulations established in or pursuant to this chapter shall be permitted to discharge effluent into the System provided there exists adequate sewer service available to which he can connect.

"2.66. Prohibited Substances. Except as hereinafter provided no person shall discharge or cause to be discharged any of the following substances into the sanitary or combined sewer:

(1) Any effluent having a temperature higher than 104 degrees F.

(2) Any effluent which contains more than 50 mg/l of animal fat, vegetable fat, oil or grease, or any combination thereof.

(3) Any gasoline, benzene, naphtha, fuel oil or other inflammable or explosive liquid, solid or gas.

(4) Any grease, oil or other substance that will become solid or viscous at temperatures 60 degrees Celsius and below after entering the System.

(5) Any substance from the preparation, cooking and dispensing of food and from the handling, storage and sale of produce which has not been shredded to such a degree that all particles shall be carried freely under flow conditions normally prevailing in the public sanitary or combined sewer, with no particle larger than one-half inch in any dimension.

(6) Any substance capable of causing obstruction to the flow in sewers or other interference with the proper operation of the sewage disposal system including but not limited to mineral oil, grease, ashes, cinders, sand, mud, plastics, wood, paunch manure, straw, shavings, metal, glass, rags, feathers, asphalt, tar and manure.

(7) Any effluent pH lower than 6.0 or higher than 10.0 or having any other corrosive properties capable of causing damage or hazard to structures, equipment or personnel of the treatment works.

(8) (a) Any effluent in excess of:

1.5 mg/l of Cadmium as Cd.
6 mg/l of Zinc as Zn.
2 mg/l of total Chromium as Cr.
1.5 mg/l of Copper as Cu.
1 mg/l of Cyanide as CN.
1.5 mg/l of Nickel as Ni.
.02 mg/l of Phenol or derivative of Phenol.

(b) Any discharge of phosphorus ammonia, nitrates, sugars or other nutrients or waste waters containing them which have an adverse effect on treatment processes or cause stimulation of growths of algae, weeds, or slimes which are or may become injurious to water supply, recreational use of water, fish, wildlife and other acquatic life.

(9) Any paints, oils, lacquers, thinners or solvents including any waste containing a toxic or deleterious substance which impair the Sewage Treatment process or constitute a hazard to employees working in the Sewage Disposal System.

(10) Any noxious or malodorous gas or substance capable of creating a public nuisance.

(11) Any effluent of such character or quantity that unusual attention or expense is required to handle such materials at the sewage treatment plant or to maintain the System.

(12) Any discoloration such as, but not limited to, dyes, inks, and vegetable tanning solutions, or any unusual chemical oxygen demand, chlorides, sulfates or chlorine requirements in such quantities as to be deleterious and a hazard to the System and its employees.

(13) Any radioactive wastes or isotopes of such half-life or concentration as may exceed limits established by applicable Local, State or Federal regulations.

(14) Any effluent containing a five (5) day biochemical oxygen demand greater than 300 mg/l.

(15) Any effluent containing suspended solids greater than 350 mg/l.

(16) Any effluent containing phosphorus greater than 40 mg/l.

(17) Any effluent having an average daily flow greater than 2% of the System's average daily flow.

The Director upon review may approve discharges in excess of the limits set forth in subsections 14 through 17 subject to conditions either set forth in this chapter or special conditions he deems necessary in order to preserve and protect public health, safety and welfare, subject to conformance with the applicable State and Federal law.

"2.67. Inspection. The Director and other duly authorized employees of the City bearing proper credentials and identification shall be permitted to enter upon all properties at reasonable times for the purpose of inspection, observation, measurement, sampling and testing in accordance with the provisions of this chapter and any rules and regulations adopted pursuant hereto. Any person who applies for and/or receives services from this System under this chapter shall be deemed to have consented to inspections pursuant to this section, including entrance upon that person's property at reasonable times to make inspections.

"2.68. Use of Storm Sewers. No person shall discharge or cause to be discharged into any storm sewer or natural or artificial water course, effluent other than storm water or uncontaminated effluent, except with authorization by a National Pollution Discharge Elimination System permit, and with the approval of the City's Director of Environmental Protection.

"2.69. Protection from Damage. No unauthorized person shall maliciously, willfully or negligently break, damage, destroy, uncover, deface or tamper with or alter any structure, property, appurtenance, equipment or any other item which is part of the Sewage Disposal System.

"2.70. Enforcement. Any person found to be violating any of the provisions of this chapter shall be guilty of a violation of the Code. The Director is hereby authorized to bring any appropriate action in the name of the City of Grand Rapids, as may be necessary or desirable to restrain or enjoin any public nuisance, to enforce any of the provisions of this Chapter, to initiate criminal prosecution, and in general to carry out the intent and purpose of this chapter."

INDUSTRIAL SEWER USE REGULATIONS

R-1. Industrial Cost Recovery System - All industrial users, connected to the Grand Rapids Sewage Disposal System, shall be required to pay their share of existing EPA grants and any grant or grants awarded pursuant thereto, divided by the recovery period. All industrial users shall share proportionately, based on flow, in the recovered amounts. Industrial users shall also pay a surcharge on Biochemical Oxygen Demand (BOD) and Suspended Solids (SS) on individual plant effluents in excess of 300 mg/l of BOD and 350 mg/l of SS.

R-2. Inspection - When required by the Director, the owner or occupant of any property served by a sewer carrying industrial or commercial waste shall install one or more suitable control manholes to facilitate observation, sampling and measurement of discharges. Such manholes when required shall be accessible and safely located and shall be constructed in accordance with plans approved by the Director. The manholes shall be installed by the owner at his expense and shall be maintained by him so to be safe and accessible at all times, in the event that no manhole has been required, the Director shall designate a proper sampling point.

R-3. Testing Method - All measurements, tests, and analyses of the characteristics of discharges shall be determined in accordance with standard methods, herein defined, and shall be determined by taking suitable samples at designated sampling points. Such sampling shall be an appropriate manner of determining both compliance with the requirements and penalties specified in the Ordinance.

The City and all users of the Sewage Disposal System shall employ one of the following standard methods for the analysis of effluent:

a. Standard Methods for the Examination of Water and Wastewater, available from the American Public Health Association;

b. American Society for Testing and Materials (ASTM) Annual Book of Standards, Part 31; or

c. Environmental Protection Agency Methods for Chemical Analysis of Water and Wastes.

Users shall maintain a sampling frequency which insures that Ordinance limitations for effluent are met.

R-4. Industrial Surveillance Program - The City shall sample industrial effluent entering the Sewage Disposal System. One of two methods of industrial surveillance shall be utilized for each industry:

a. For those industries contributing toxic or deleterious substances regulated and controlled by the City Sewer Use Ordinance, the following procedure shall be followed: A grab sample shall be taken at the designated sampling point.

b. For those industries contributing non-toxic wastes exceeding amounts specified by the City Sewer Use Ordinance, the following procedure shall be followed: Three twenty-four (24) hour composit samples shall be taken at the designated sampling point during each quarterly billing period.

Tests on all industrial surveillance samples shall be performed in accordance with Standard Methods for the Examination of Water and Wastewater.

R-5. Penalty Charge Methods (Surcharge) - All users of the Sewage Disposal System shall be subject to penalty charges for effluent containing Biochemical Oxygen Demand (BOD) in excess of 300 milligrams per liter, and Suspended Solids (SS) in excess of 350 milligrams per liter. The City shall collect three (3) twenty-four (24) hour composite samples from each designated sampling point once each billing period, and base the surcharge cost upon such samples. The penalty charge shall be calculated by an employee designated by the Director and billed quarterly by the Water Department.

R-6. Preliminary Treatment Facilities - Where necessary, in the opinion of the Director, the owner shall provide at his expense, such preliminary treatment as may be necessary to:

a. Reduce the biochemical oxygen demand to 300 mg/l and the suspended solids to 350 mg/l, or

b. Control toxic or deleterious substances, or

c. Control the quantities and rates of discharge of such water and wastes.

Plans and specifications and any other pertinent information relating to proposed preliminary treatment facilities shall be submitted for review by the Director. No construction of such facilities shall be commenced until the review has been completed.

Where preliminary treatment facilities are provided for any discharges, they shall be maintained continuously in satisfactory and effective operation, by the owner at his expense. Any person required to utilize preliminary treatment facilities shall, upon request of the Director, submit to the Director, records of samplings taken from waste discharges.

R-7. Septic Tank Waste - Disposal of commercially hauled septic tank waste into the Sewage Disposal System shall be prohibited, except that the Director may authorize disposal of portable containers of domestic waste, including waste from recreational vehicles and highway rest areas. If such disposal is authorized, the Director shall determine and collect the cost of treating said waste.

R-8. Disposal of Sludge from Pretreatment Systems - Sludge from an industrial or commercial pretreatment system shall not be placed into the Sewage Disposal System. Such sludge shall be disposed of by a licensed hauler in a site approved by the Michigan Department of Natural Resources.

REFERENCES

1. Seminar on Pretreatment of Industrial Waste, Environmental Protection Agency, Technology Transfer, Cincinnati, OH (1978).
    a. Biener, J. A. and Bouma, W. H., "Case History: City of Grand Rapids, Michigan, Program of Industrial Waste Control."
    b. Dyer, J. C., "Local Pretreatment Program Requirements."
    c. Schwartz, H. G., Jr., and Buzzell, J. D., Jr., "The Impact of Toxic Pollutants on Municipal Wastewater Systems."
    d. Steffen, A. J., "Effects and Removability of Industrial Pollutants."
    e. Vernick, A. S., Feiler, H. D., Lanik, P. D., "Elements of an Industrial Waste Control Program."

2. Environmental Protection Agency Pretreatment Standards, 43, Federal Register, 27746 (June 26, 1978).

3. Brody, J., et al., "Performance Indicators for Wastewater Collection Systems," Journal Water Pollution Control Federation, 51, pp. 695-708 (1979).

4. Kerri, K. and Brady, J., Operation and Maintenance of Wastewater Collection Systems, Training Manual, University of California at Sacramento, Sacramento, CA (1976).

5. Process Design Manual for Sulfide Control in Sanitary Sewer Systems, Technology Transfer, Environmental Protection Agency, Cincinnati, OH (1974).

6. Industrial Waste Monitoring, Technology Transfer, Environmental Protection Agency, Cincinnati, OH (1974).

7. Regulation of Sewer Use, MOP 3, Water Pollution Control Federation, Washington, D.C.

8. Sewer Maintenance, MOP 7, Water Pollution Control Federation, Washington, D.C.

9. Design and Construction of Sanitary and Storm Sewers, MOP 9, Water Pollution Control Federation, Washington, D.C.

10. Handbook for the Evaluation and Rehabilitation of Wastewater Collection Systems, Environmental Protection Agency, Washington, D.C. (1976).

11. Schwartz, H. G. and Buzzell, J. C., "The Impact of Toxic Pollutants on Disposal from Wastewater Systems," Industrial Water Engineering, pp. 14-20, October-November, 1978.

12. Hall, R. M., "EPA's New Pretreatment Program," Industrial Water Engineering, pp. 8-14, September, 1978.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 4: Pre/Primary Treatment

Unit 4 of 15 Units of Instruction

Lessons in Units: 2 Recommended Time: 1 3/4 hours

Instructor Overview of Lesson

Rationale for Unit: Proper operation of preliminary and primary treatment units is essential to effective overall treatment plant performance because of their critical function to protect the treatment plant equipment and processes and to some degree to regulate loadings to the plant. Because these units accomplish simple physical removal by screening, grinding and gravity separation, their operation is often taken for granted. This unit focuses on the purposes of preliminary and primary treatment units and relates improper performance of these units to problems which appear in downstream processing units. The unit applies the *Process of Troubleshooting* to evaluation and problem solving in pre/primary treatment and develops trainee skills in applying the *Process of Troubleshooting*.

Trainee Entry Level Behavior: The trainee will have completed Unit of Instruction 1: *Overview* and Unit of Instruction 2: *Elements of Troubleshooting* before beginning Unit of Instruction 4: *Pre/Primary Treatment.*

Trainee Learning Objectives: At the conclusion of this Unit of Instruction, the trainee will be able to:

1. List, from memory, the process units normally used for preliminary treatment of wastewater and describe the purpose of each process unit in the treatment of wastewaters.

2. From memory, describe the purposes and benefits of flow equalization and describe expedients which the troubleshooter may use to implement flow equalization at a treatment facility.

3. Given verbal descriptions and/or photographs of treatment plant conditions, apply the *Process of Troubleshooting* to identify and recommend solutions to problems which occur in preliminary and primary treatment processes.

4. Using notes and references, list at least eight problems which commonly occur in primary treatment plants, the probable causes of the problem and the alternative actions available to correct the problem and prevent its recurrence.

Sequencing and Pre-Course Preparation for the Unit: Unit 4, *Pre/Primary Treatment*, is presented as two lessons:

Lesson 1: Preliminary Treatment

Recommended Time: 55 minutes

Purpose: Presents the purpose, functions and sequencing of preliminary treatment units, discusses flow equalization as a troubleshooting tool and identifies common problems in preliminary treatment.

Training Facilities:

a. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees in groups of four;

b. Instructor table with lectern;

c. Large projection screen (6' x 6' minimum) and chalkboard in front of room and readily visible to all trainees;

d. Easel with pad;

e. 35mm carousel projector with remote control changer at instructor table;

f. At least four empty carousel trays;

g. Overhead projector;

h. Chalk, felt-tip markers and erasers;

i. Six to eight chairs randomly spaced at back and sides of room for visitors.

Pre-Course Preparation:

1. Reproduce and place in *Trainee Notebook*, pages T4.1.1 - T4.1.24.

2. Provide each trainee a copy of *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*.

Instructional Approach: Illustrated lecture, trainee problem solving and class discussion.

Lesson 2: Troubleshooting Primary Treatment

Recommended Time: 50 minutes

Purpose: Applies the *Process of Troubleshooting* to primary treatment and identifies problems commonly encountered in primary treatment.

Training Facilities: As specified in Unit 4, Lesson 1.

Pre-Course Preparation: Provide each trainee a copy of *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities.*

Instructional Approach: Illustrated lecture, trainee problem solving and class discussion.

Presentation Options for the Course Director: The 105 minute Unit *Pre/Primary Treatment* is an important introduction to the technical content of this course. It stresses the use of the *Process of Troubleshooting* to solve operational problems in treatment plant components, a theme which is repeated throughout the course. However, the unit covers this technical material very briefly and in less detail than comparable material is covered in the following units.

The developers of the course have found, from the trial presentations, that trainees for whom this course is targeted do not require detailed review of the preliminary and primary treatment processes and generally find it to be an inefficient use of course time when more detail is provided. Additionally, trainees for whom this material would be new, and therefore useful, most likely are not experienced enough in waste treatment plant operations to benefit from the remaining units or, in other words, they do not meet the entry level requirements of the course. It is recommended that this Unit not be significantly expanded.

There are some alternatives for varying this Unit.

If more detail is desired on the preliminary treatment processes, the following alternatives may be used.

a. Lesson 1, Introduction to Lesson and Purpose of Pretreatment may be expanded to any desired length by using slides showing and diagrams depicting the various pretreatment process components. If this section is expanded, emphasis should be given to operational problems that occur in each component and how those problems may be prevented and corrected.

b. If time permits and an appropriate treatment plant is available, an inspection of various pretreatment components and how they are maintained could be instructive.

Summary of Unit of Instruction 4: Pre/Primary Treatment

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Preliminary Treatment 55 minutes	1. Recognize importance of preliminary treatment	1. Preliminary Treatment purposes and functions	1. Trainee problem solving and discussion	1. *Trainee Notebook*, pages T4.1.1 - T4.1.24.
	2. Identify preliminary treatment problems	2. Uses of flow equalization	2. Illustrated lecture using lesson outline and slides	2. *Instructor Notebook*, pages 4.1.1 - 4.1.17.
	3. Apply visual observations to problem identification	3. Typical preliminary treatment problems		3. Slides 179.2/ 4.1.1 - 179.2/ 4.1.34.
	4. Practice the Process of Troubleshooting	4. Observations to make in preliminary treatment processes		
2. Primary Treatment 50 minutes	1. Apply the Process of Troubleshooting to Primary Treatment	1. Steps in the process of troubleshooting	1. Illustrated lecture using lesson outline and slides	1. *Trainee Notebook*, pages T4.2.1 - T4.2.3.
	2. Identify common problems in primary treatment	2. Data needed to evaluate primary treatment	2. Class discussion	2. *Instructor Notebook*, pages 4.2.1 - 4.2.16.
		3. Common problems in primary treatment operations		3. Slides 179.2/ 4.2.1 - 179.2/ 4.2.34.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 4: Pre/Primary Treatment

Lesson 1: Preliminary Treatment

Lesson 1 of 2 Recommended Time: 55 minutes

Purpose: This lesson emphasizes the importance of preliminary treatment processes in obtaining maximum performance from a wastewater treatment facility by relating poor preliminary treatment unit performance to downstream process problems. The purposes, functions and sequencing of preliminary treatment units are presented. Flow equalization as a practical troubleshooting tool is discussed. Preliminary treatment problems are identified in student problem solving which stresses the plant visit and visual observation steps in the *Process of Troubleshooting*.

Trainee Entry Level Behavior: The trainee should have completed Unit of Instruction 1: *Overview* and Unit of Instruction 2: *Elements of Troubleshooting* before beginning the Unit on *Pre/Primary Treatment*. Completion of Unit of Instruction 3: *Sewer Use Control* is recommended but is not an essential prerequisite to Unit of Instruction 4.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. List, from memory, the process units normally used for preliminary treatment at a publicly owned treatment works and describe the purpose and function of each unit.
2. From memory, explain the importance of visual observations in troubleshooting and cite at least two examples which show how visual observations can be used to identify problems in preliminary treatment process operations.
3. From memory, describe and explain the benefits of flow equalization to treatment facility operations and explain how the troubleshooter can use the flow equalization concept as a tool in troubleshooting an existing wastewater treatment facility.
4. From memory, explain how inadequate preliminary treatment can affect downstream operations and cite at least one example of a downstream problem caused by inadequate preliminary treatment process operations.

Instructional Approach: Illustrated lecture, trainee problem solving and class discussion. It is suggested that the instructor follow the lesson outline provided.

Lesson Schedule: The 55 minutes allocated to this lesson should be scheduled as follows:

TIME	ACTIVITY
0 - 10 minutes	Trainee Problem Solving
10 - 20 minutes	Class Discussion of Problem
20 - 30 minutes	Purpose of Preliminary Treatment
30 - 35 minutes	Flow Equalization
35 - 55 minutes	Visual Observations in Preliminary Treatment Problem Identification

Trainee Materials Used in Lesson:

1. *Trainee Notebook,* pages T4.1.1 - T4.1.2, "Troubleshooting Problem - Preliminary Treatment."
2. *Trainee Notebook,* pages T4.1.3 - T4.1.24 , "Flow Equalization."
3. *Trainee Notebook,* pages T4.2.3 , "References."
4. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities.*

Instructor Materials Used in Lesson:

1. *Instructor Notebook,* Unit 4, Lesson 1, pages 4.1.1 - 4.1.17.
2. Slides 179.2/4.1.1 - 179.2/4.1.34.

Instructor Materials Recommended for Development: The instructor may wish to develop problems from his/her experience to substitute for the problems used in the lesson plan. Problems used should be restricted to those encountered in preliminary treatment process operations which have an impact on performance of downstream processes. Problems which stress the importance of visual observations and their interpretations as a troubleshooting tool are preferred.

Additional Instructor References:

1. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA/430/9-78-001, Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (1978).

2. *Inspectors Guide for Evaluation of Municipal Wastewater Treatment Plants*, EPA/430/9-79-010, Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (1979).

3. *Process Design Manual for Upgrading Existing Wastewater Treatment Plants*, Environmental Protection Agency, Technology Transfer, Cincinnati, OH (1974).

4. *Manual of Instruction for Sewage Treatment Plant Operators*, New York State Department of Health, Albany, NY.

5. *Operation of Wastewater Treatment Plants, A Home Study Course*, University of California at Sacramento, Sacramento, CA (1970).

6. *Operation of Wastewater Treatment Plants*, MOP 11, Water Pollution Control Federation, Washington, D.C. (1976).

7. *Manual of Wastewater Operations*, Texas Water Utilities Association, Austin, TX (1971).

Classroom Set-Up: As specified in the "Instructor Overview to the Unit of Instruction, *Instructor Notebook*, page 4.2.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Applying the Process of Troubleshooting - Trainee Problem Solving (10 min.)	Use Slide 179.2/4.1.1
A. Refer class to *Trainee Notebook*, page T4.1.1 for a statement of the problem. Give the class about one (1) minute to read through the background information.	Slide 179.2/4.1.1 is a blank used to blacken the screen.
B. Use Slide 179.2/4.1.2 to illustrate to the class what was observed at the plant.	Use Slide 179.2/4.1.2
C. Refer class to *Trainee Notebook*, page T4.1.2 and ask them to answer the questions about the problem at this plant. Inform class that they should work with their work group to solve the problem.	Slide 179.2/4.1.2 is a photograph which shows an operator standing on a surface mechanical aerator removing rags from the aerator. The operator is smoking and has no life jacket, safety lines or other protective gear.
D. Give class about 10 minutes to work on the problem. Leave Slide 179.2/4.1.2 on throughout problem solving exercise.	Leave Slide 179.2/4.1.2 on throughout problem solving and reporting exercises.
E. Circulate about the classroom to observe work group progress and stimulate discussion in the work groups.	
F. After 10 minutes call work to a halt for trainees to report and discuss their findings.	
II. Class Discussion of Problem (10 min.)	
A. "What is the location of the problem shown in the slide?"	
1. Call on one work group to report their findings for the question.	
2. Provide opportunity for other groups to discuss the answer reported.	
3. Most likely answer: Surface mechanical aerator in the activated sludge aeration basin.	Note: There may be more than one plausible answer to each question. There is no single right answer. Several could be acceptable.

B. "What is the nature of the problem?"

1. Call on another work group to report their findings for the question.
2. Provide opportunity for discussion of the answer reported.
3. Most likely answer: Trash (rags) being pulled from the aerator turbine blades. Trash accumulation on turbine blades reduced oxygen transfer efficiency causing low DO and inadequate mixing in the aeration basin. It's possible that aerator "kicked off" because motor overloaded and overheated, although can't tell how the problem was detected from the information given.

C. "What is the most likely cause of the problem based upon your knowledge of the plant as a troubleshooter?"

1. Call on another group to report their findings.
2. Allow time for discussion of the response.
3. Most likely answer: Inadequate comminution, screening and/or primary sedimentation resulting in trash and rags passing through to the aeration basin. An alternative cause is "roping" where comminuted rags are reforming in the aeration basin.

Actual Cause from Case History Report:

The comminutor is out of service and has been out for several months. Inquiry disclosed that a request for repair had been submitted several months before but the city manager elected not to repair the

Have class comment on significance of city manager's failure to respond to the request to repair the comminutor.

LESSON OUTLINE

KEY POINTS &
INSTRUCTOR GUIDE

comminutor. Consequently, the plant suffered frequent aerator outages because of rag accumulation.

D. "What corrective action would you recommend?"

1. Call on another work group to report their recommendations.

2. Encourage class discussion of the reported recommendations.

3. Responses sought include:

   a. Immediate correction: Set up routine for scheduled shutdown and cleaning of aerator turbines to try to keep aeration and mixing efficiency up.

   b. Repair the comminutor.

   c. Improve screening at headworks with emphasis on easier procedures to clean screen and remove screenings.

   d. Information given indicates that this is but one symptom of deeper problems:

      (1) Inadequate management support
      (2) Inadequate staffing
      (3) Possible skills deficiencies with operator, laboratory and management training needed
      (4) Perhaps other equipment problems as result of inadequate maintenance programs

4. Emphasize the following points to the class:

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
a. Corrective actions are both immediate and long term.	
b. Downstream problems were caused by failure of preliminary treatment unit, the comminutor.	
c. Thorough troubleshooting evaluation is needed to determine and solve the deeper causes of this plant's problems.	
E. "Do you see additional problems shown in the slide?"	
1. Call on work group to answer.	
2. Encourage class discussion.	
3. Answer sought: Major safety problems:	
a. Man on aerator	
b. No safety lines or life jacket	
c. No gloves or protective clothing	
d. Smoking	
	Use Slide 179.2/4.1.3 Slide 179.2/4.1.3 is a blank used to blacken screen
III. Introduction to Lesson and Purpose of Pretreatment (10 min.)	
A. Lesson Objectives	Guide: Instructor should introduce lesson by stating its objectives, and briefly relating lesson content to the course emphasis on troubleshooting.
1. To present a treatment plant as a system, with operations at one process related to performance at others.	
2. To make troubleshooters cognizant of of the opportunity to prevent treatment	Use problem solved in Section I to illustrate lesson objectives.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
plant problems and enhance performance by upgrading pretreatment operations.	
3. To demonstrate the usefulness of the Troubleshooting Process in solving operational problems.	
B. Purpose of Pretreatment - To prepare inflowing wastewater to maximize downstream plant performance and waste removal. Pretreatment serves to:	Emphasize the importance of pretreatment processes in overall plant performance.
1. Prevent the addition of materials to the influent which would pass thru the plant untreated.	
2. Prevent the addition of materials which would injure or reduce the effectiveness of downstream processes.	
3. Treat incoming wastes so as to upgrade downstream performance.	
4. Minimize total capital and operating costs of sewage treatment.	
C. Some functions accomplished through pretreatment are:	Guide: Note that Sewer Use Ordinances compliment Pretreatment and are a very important device in accomplishing the purpose of Pretreatment. Refer to Unit 3, *Sewer Use Control*, for more detailed discussion of sewer use ordinance and industrial pretreatment.
1. Prevention of detrimental industrial wastes.	
2. Treatment of industrial wastes to make them compatible with sewage.	
3. Equalize and balance flows and hydraulic loadings (flow equalization).	
4. Reduce the size of coarse materials in influent.	
5. Remove coarse materials from influent.	
6. Eliminate or prevent anaerobic conditions.	

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

7. Removal of grease, oil and scum.

8. Addition of chemicals to improve downstream treatability.

D. Components of Pretreatment

1. Briefly review the possible components of pretreatment in a treatment plant.

   a. Raw sewage pumping
   b. Screening
   c. Grinding (comminution)
   d. Grit removal
   e. Preaeration
   f. Prechlorination (odor or septicity control)
   g. Flow equalization

Refer class to *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* for detailed discussion of preliminary treatment units.

2. Many also add chemicals at headworks to:

   a. Control pH
   b. Precipitate metals
   c. Coagulate to improve suspended solids removal
      (1) Ferric chlroide
      (2) Alum
      (3) Polymers
   d. Phosphorous removal
   e. Others? Ask class.

IV. Flow Equalization (5 min.)

A. Refer class to *Trainee Notebook*, pages T4.1.3 - T4.1.24 for more detailed discussion of flow equalization.

B. Purposes and Benefits

Use Slide 179.2/4.1.4

1. Use Slide 179.2/4.1.4 to summarize purposes and benefits of flow equalization.

Slide 179.2/4.1.4 reads:

LESSON OUTLINE

2. Tell class that by dampening of load extremes the plant is subjected to fewer rapid load changes making it easier to operate the plant efficiently.

C. Refer to pages T4.1.5, T4.1.10 and T4.1.14 in the *Trainee Notebook* and briefly discuss the following:

   1. Flow diagrams for in-line and side-line equalization (page T4.1.5).

   2. Flow and BOD variation before and after equalization (page T4.1.10 and T4.1.14).

D. How to utilize equalization

   1. Very few plants have built-in equalization, yet many have problems due to load fluctuations and excessive peak loads.

   2. If troubleshooter can trace operational problems and process upsets to peaks in load then he/she can recommend flow equalization methods.

   3. Use Slide 179.2/4.1.5 to illustrate troubleshooting expedients for flow equalization. Note that one thing troubleshooter should always look for is piping and tank flexibility which will allow some load balancing.

KEY POINTS & INSTRUCTOR GUIDE

"Purpose and Benefits of Equalization

* Dampen hydraulic and organic overloads
* Reduce need for additional treatment capacity
* Improve treatment efficiency"

Use Slide 179.2/4.1.5

Slide 179.2/4.1.5 reads:

"Flow Equalization Methods

* Use any available storage capacity
    * Spare tank
    * Unused clarifiers
* Ponding or holding area
* Vary levels in ditches or ponds to equalize flows"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
4. Design considerations	
a. Troubleshooters must be aware of problems caused by improper design of flow equalization facilities, such as: (1) Solids deposition (2) Air requirements (3) Scum removal (4) Bank design	
5. "Creative" troubleshooters can often devise means for flow equalization with the help of some available tankage, piping or hose, pumps and valves.	Guide: See if trainees can suggest other means of flow equalization
6. For flow equalization to be effective, accurate flow measurements are needed.	
V. Visual Observations in Preliminary Treatment Problem Identification (20 min.)	
A. Lesson Approach	
1. The instructor will show a series of 14 slides which are used to illustrate ten problems. Each slide should remain on the screen for about one (1) minute. As each picture is shown the trainees will try to identify: a. Location of the problem. b. Nature of the problem. and record their observations in their *Trainee Notebook*. After the ten problems have been completed, the instructor will repeat the sequence and the class will discuss their findings.	
2. Describe to the class what you and they are to do.	

a. Instructor will show one or more slides illustrating a problem.

b. Trainees are to observe the slide and record in their *Trainee Notebook*:

(1) Location of the problem.
(2) Nature of the problem.

c. Take about 10 minutes to go through problems, then another 10 minutes to discuss the problems.

3. Before showing slides, announce that the situation is not truly representative of troubleshooting in a plant. In the plant the troubleshooter would:

a. Know where he/she is.

b. Smell what's happening.

c. Talk to the operator.

d. Poke around.

e. Take samples and run analyses.

B. Read problems to class and show slides while trainee record.

MOVE THROUGH SLIDES QUICKLY!

a. The location of the problem and

b. The nature of the problem.

Read the brief problem statements as you go.

1. Problem 1 - You enter the plant and observe this.

- Show Slide 179.2/4.1.6 (30 sec.) -

Use Slide 179.2/4.1.6

Slide 179.2/4.1.6 is a photograph showing the plant influent channel. Everything looks normal.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
Thirty seconds later you look back and see this where the channel used to be. - Show Slide 179.2/4.2.7 (30 sec.) -	Use Slide 179.2/4.1.7 Slide 179.2/4.1.7 is a photograph of the influent channel in Slide 179.2/4.1.6 which is now completely filled and overflowing.
2. Problem 2 - These are two locations in the same plant with the same problem. - Show Slide 179.2/4.1.8 (30 sec.) -	Use Slide 179.2/4.1.8 Slide 179.2/4.1.8 is a photograph showing a white chemical drum (deodorant or H_2O_2) feeding into inlet channel.
- Show Slide 179.2/4/1.9 (30 sec.) -	Use Slide 179.2/4.1.9 Slide 179.2/4.1.9 is a photograph showing drums of chemicals being fed to an inlet channel.
3. Problem 3 - This is one situation where the troubleshooter's nose would come in handy. - Show Slide 179.2/4.1.10 (60 sec.)	Use Slide 179.2/4.1.10 Slide 179.2/4.1.10 is a photograph of an inlet channel showing bright red influent (blood from chicken processing waste).
4. Problem 4 - No, this is not a lab test for a dishwashing detergent. - Show Slide 179.2/4.1.11 (60 sec.)	Use Slide 179.2/4.1.11 Slide 179.2/4.1.11 is a photograph showing an inlet channel filled with a black liquid covered with a thick billowing white foam (a tannery waste).
5. Problem 5 - Unlike many plant problens, this equipment appears to be in perfect working order. - Show Slide 179.2/4.1.12 (60 sec.)	Use Slide 179.2/4.1.12 Slide 179.2/4.1.12 is a photograph showing a well-used by-pass gate ahead of the bar screen.
6. Problem 6 - This location, outside of the plant, was not too far from the plant headworks.	Use Slide 179.2/4.1.13 Slide 179.2/4.1.13 is a photograph

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
- Show Slide 179.2/4.1.13 (60 sec.) -	of a by-pass discharging outside the plant.
7. Problem 7 - The flow shown here smells as bad as it looks.	Use Slide 179.2/4.1.14
- Show Slide 179.2/4.1.14 (60 sec.) -	Slide 179.2/4.1.14 is a photograph of an automatically cleaned grit chamber filled with black, obviously septic, material with grease and gas bubbles on the surface.
8. Problem 8 - So this is the grit hopper?	Use Slide 179.2/4.1.15
- Show Slide 179.2/4.1.15 (60 sec.) -	Slide 179.2/4.1.15 is a photograph showing excess trash and rags in the grit being removed by conveyor from an automatically cleaned grit chamber.
9. Problem 9 - The operator was very proud of his tight collection system because very little grit was ever removed from the influent.	Use Slides 179.2/4.1.16 - 179.2/4.1.18
- Show Slide 179.2/4.1.16 (20 sec.) - - Show Slide 179.2/4.1.17 (20 sec.) - - Show Slide 179.2/4.1.18 (20 sec.) -	Slides 179.2/4.1.16 - 179.2/4.1.18 are a series of photographs showing influent discharging at high velocity across the buckets of the grit elevator causing all grit collected to be washed back into the grit chamber.
10. Problem 10 - Some operators practice horticulture as a hobby.	Use Slide 179.2/4.1.19
- Show Slide 179.2/4.1.19 (60 sec.) -	Slide 179.2/4.1.19 is a photograph of a grit chamber partially filled with grit and showing plants growing on accumulated grit. The wastewater is black and septic looking.
C. Review problems with class	
1. Show slides and let class identify location and problem. Add to class input as needed.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Results	
a. Problem 1	
(1) Plant inlet and grit chamber	Use Slide 179.2/4.1.20 Same as Slide 179.2/4.1.6
(2) Overflow caused by raw sewage pump surge - adjust pump controls.	Use Slide 179.2.4.1.21 Same as Slide 179.2/4.1.7
b. Problem 2	
(1) Various locations in headworks.	Use Slide 179.2/4.1.22 Same as Slide 179.2/4.1.8
(2) Masking agents being used unsuccessfully to hide odor problems from septic sewage.	Use Slide 179.2/4.1.23 Same as Slide 179.2/4.1.9
c. Problem 3	
(1) Headgate area	Use Slide 179.2/4.1.24 Same as Slide 179.2/4.1.10
(2) Red flow plus odor signified chicken packing waste - feathers and fat can be found by looking around.	
d. Problem 4	
(1) Headgate area	Use Slide 179.2/4.1.25 Same as Slide 179.2/4.1.11
(2) Foam signified serious industrial waste problem - in this case a tannery waste.	
e. Problem 5	
(1) Screen	Use Slide 179.2/4.1.26 Same as Slide 179.2/4.1.12
(2) Operative by-pass gate which appears to be well used.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
f. Problem 6	
(1) Outside plant near sewer manhole	Use Slide 179.2/4.1.27 Same as Slide 179.2/4.1.13
(2) Construction by-pass line was still used as by-pass after construction.	
g. Problem 7	
(1) Grit chamber	Use Slide 179.2/4.1.28 Same as Slide 179.2/4.1.14
(2) Septic waste with grease and gas bubbles rising. Sludge on bottom of chamber.	
h. Problem 8	
(1) Grit chamber	Use Slide 179.2/4.1.29 Same as Slide 179.2/4.1.15
(2) Trash and rags being removed in grit chamber indicating inadequate upstream screening.	
i. Problem 9	
(1) Grit chamber	Use Slide 179.2/4.1.30 Same as Slide 179.2/4.1.16
(2) Turbulence, jet inlet and high flow prevented removal of grit. Note the clean buckets.	Use Slide 179.2/4.1.31 Same as Slide 179.2/4.1.17 Use Slide 179.2/4.1.32 Same as Slide 179.2/4.1.18
j. Problem 10	
(1) Grit chamber	Use Slide 179.2/4.1.33 Same Slide 179.2/4.1.19
(2) Operator gave up on removing grit. "It'll only fill up again anyway." Also note septic looking sewage.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
VI. Summary	
A. Preliminary treatment operations are often taken for granted but good preliminary treatment can prevent many downstream problems.	Use Slide 179.2/4.1.34 Slide 179.2/4.1.34 is a blank used to blacken screen.
B. Careful observation of what's happening in the headworks area can give many clues to problem causes, particularly those that are caused in the collection system.	
C. Use any time remaining for discussion.	
D. Direct class to next activity on agenda.	

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 4: Pre/Primary Treatment

Lesson 1: Preliminary Treatment

Trainee Notebook Contents

Troubleshooting Problem - Plant Information and Background T4.1.1

Troubleshooting Problem - Problem Worksheet T4.1.2

Flow Equalization Article T4.1.3

Troubleshooting Problem - Preliminary Treatment

Plant Information and Background

Group # ________

Plant Background:

Plant flow is 10.0 MGD

Essential equipment:

1. Pump station following a 2 inch bar screen
2. Comminutor in alternate channels
3. Raw sewage pumps, coarse bar screen, comminutor and manually cleaned grit chamber are in a below grade pit
4. Contact stabilization activated sludge with surface mechanical aerators
5. Final clarifiers (2)
6. Anaerobic digesters

Initial Observation and Analysis by Troubleshooter:

The plant facility has what appears to be adequate capacity but little versatility. Preliminary screen has an open channel behind it with poor facilities for cleaning screens and lifting screenings from the pit (approximately 15 feet down). Flow distribution, measurement and control devices require real ingenuity and agility to master the situation and to achieve effective plant performance.

Observations on Management Behavior:

1. Laboratory facilities and support appear weak.
2. The plant is understaffed.
3. Comments from staff lead you to believe that they get little support from city hall for their problems.
4. Staff appear to be hardworking and trying.
5. Records are scant except for the absolute minimum. There is little confidence in the records, except that they accurately show that the plant is not performing up to its design.
6. Process controls are limited. The staff is too busy just keeping the wastewater moving and solving problems like the one shown in the slide.

Troubleshooting Problem - Preliminary Treatment

Problem Worksheet

Group # _____

Trainee groups should answer the following questions.

1. What is the location of the problem shown in the slide?

2. What is the nature of the problem?

3. What is the most likely cause of the problem, based upon your knowledge of the plant as a troubleshooter?

4. What corrective actions would you recommend?

5. Do you see additional problems shown in the slide?

You have 10 minutes to complete this worksheet, at which time the problem will be discussed by the class.

CHAPTER 3

FLOW EQUALIZATION

3.1 Introduction and Concept

3.1.1 General

The cyclic nature of wastewater flows in terms of volume and strength is well recognized. Nearly all municipal wastewater treatment plants today are processing variable wastewater flows. However, improved efficiency, reliability and control is possible when physical, biological and chemical processes are operated at or near uniform conditions. For this reason, flow equalization is employed in the field of water supply and in the treatment of some industrial wastewater. Presently, the advent of more demanding water quality standards is stirring interest in the application of flow equalization to municipal wastewater treatment.

The primary objective of flow equalization basins for municipal treatment plants is simply to dampen the diurnal flow variation, and thus achieve a constant or nearly constant flow rate through the downstream treatment processes. A desirable secondary objective is to dampen the concentration and mass flow of wastewater constituents by blending the wastewater in the equalization basin. This results in a more uniform loading of organics, nutrients and other suspended and dissolved constituents to subsequent processes.

Through achieving these objectives, flow equalization can significantly improve the performance of an existing treatment facility, and is a useful upgrading technique. In the case of new plant design, flow equalization can reduce the required size of downstream facilities.

3.1.2 Variations of Flow Equalization

Equalization of municipal wastewater flows may be divided into three broad categories:

1. Equalization of dry weather flows
2. Equalization of wet weather flows from separate sanitary sewers
3. Equalization of combined storm and sanitary wastewater.

This chapter is primarily concerned with equalization of dry weather flows. This procedure provides a technique for achieving normal operation of a treatment plant under near ideal loading conditions. Its relatively low cost makes it attractive for upgrading an overloaded plant.

Increased wet weather flows in sanitary sewers is the sum of two components, infiltration and inflow. In some cases, it is feasible to equalize stormwater inflow, depending on its magnitude and duration. Infiltration from high groundwater tables can seldom be equalized. Equalization of wet weather flows from combined storm and sanitary sewers usually requires very large storage basins. The design of equalization basins to deal with these types of flow requires a special knowledge of the collection system, precipitation patterns, topography, and other factors not directly related to wastewater treatment. Strictly speaking, wet weather and combined sewer flow equalization cannot be considered as a wastewater treatment upgrading technique, and the design of such a facility is beyond the scope of this chapter. However, the concepts presented for dry weather flow equalization are generally applicable to equalization of wet weather and combined wastewater flows.

In some instances, large interceptor sewers entering the treatment plant can be effectively used as storage basins to dampen peak diurnal dry weather flow variations. In such cases, nightly or weekly drawdown of the interceptor system is necessary to flush out solids which may have been deposited during the previous storage period.

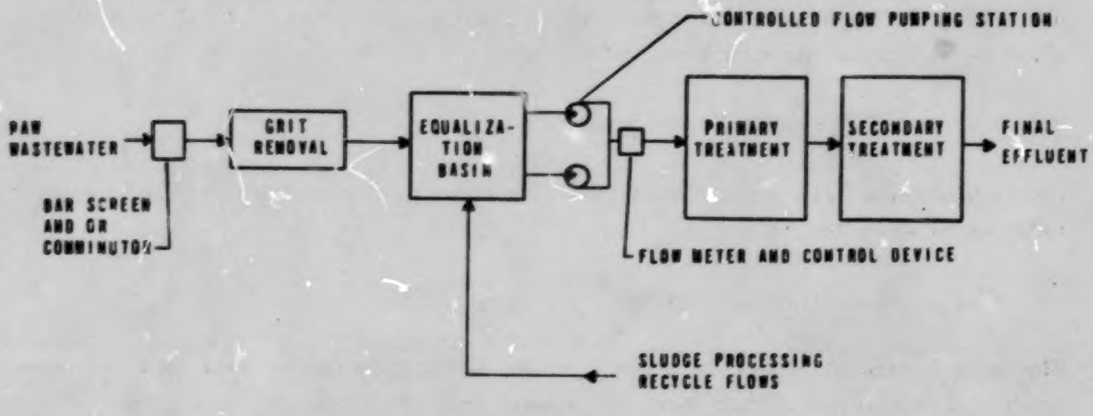
Although the use of influent sewers for equalization should not be ignored, the most positive and effective means to maximize the benefits possible with equalization is through the use of specially designed equalization basins. These basins should normally be located near the head end of the treatment works, preferably downstream of pretreatment facilities such as bar screens, comminutors, and grit chambers. Adequate aeration and mixing must be provided to keep the basins aerobic and prevent solids deposition.

It is sometimes desirable to locate the equalization basin at strategic locations within the collection system. This offers the added advantage of economically relieving trunk sewer overload during peak flow periods (1). However, it does result in the need for a pumping facility and therefore is best located where a need for pumping already exists.

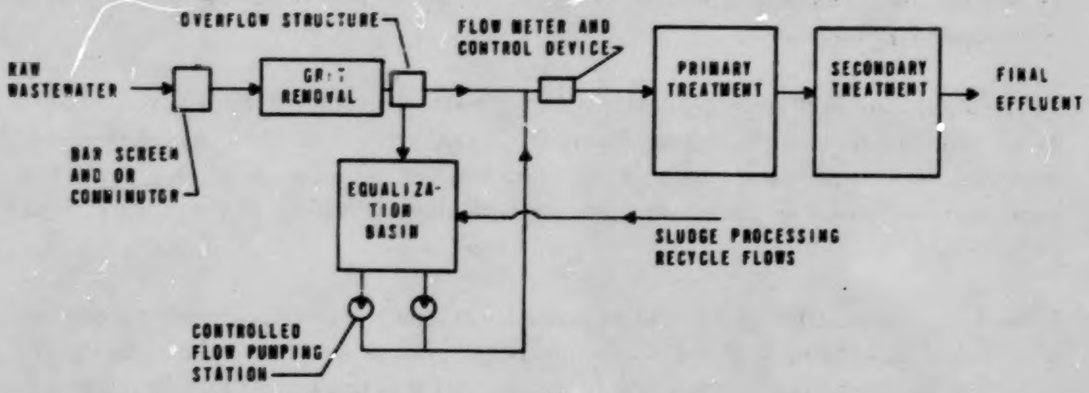
Equalization basins may be designed as either in-line or side-line units. In the in-line design shown on Figure 3-1a, all the flow passes through the equalization basin. This results in significant concentration and mass flow damping. In the side-line design shown on Figure 3-1b, only that amount of flow above the daily average is diverted through the equalization basin. This scheme minimizes pumping requirements at the expense of less effective concentration damping.

FIGURE 3-1

SCHEMATIC FLOW DIAGRAMS OF EQUALIZATION FACILITIES


CONTROLLED FLOW PUMPING STATION
RAW WASTEWATER
GRIT REMOVAL
EQUALIZATION BASIN
PRIMARY TREATMENT
SECONDARY TREATMENT
FINAL EFFLUENT
BAR SCREEN AND OR COMMINUTOR
FLOW METER AND CONTROL DEVICE
SLUDGE PROCESSING RECYCLE FLOWS

3-1a IN-LINE EQUALIZATION


OVERFLOW STRUCTURE
FLOW METER AND CONTROL DEVICE
RAW WASTEWATER
GRIT REMOVAL
PRIMARY TREATMENT
SECONDARY TREATMENT
FINAL EFFLUENT
BAR SCREEN AND OR COMMINUTOR
EQUALIZATION BASIN
SLUDGE PROCESSING RECYCLE FLOWS
CONTROLLED FLOW PUMPING STATION

3-1b SIDE-LINE EQUALIZATION

For new construction and for upgrading large plants. it is desirable to construct compartmentalized or multiple basins. This feature will allow the flexibility to dewater a portion of the facility for maintenance or equipment repair while still providing some flow equalization. Where a basin is designed for storage and equalization of wet weather flows, compartmentalized tanks will allow the utilization of a portion of the basin for dry weather flow equalization.

Single basin installations may be used for upgrading small plants, but must have the provision to be dewatered while maintaining complete treatment. This will require a bypass line around the basin to allow the downstream portion of the plant to operate unequalized when the flow equalization facility is out of service.

3.2 Benefits of Dry Weather Flow Equalization

Flow equalization has a positive impact on all treatment processes from primary treatment to advanced waste treatment.

3.2.1 Impact on Primary Settling

The most beneficial impact on primary settling is the reduction of peak overflow rates resulting in improved performance, and a more uniform primary effluent quality. Flow equalization permits the sizing of new clarifiers based on equalized flow rates rather than peak rates. In an existing primary clarifier that is hydraulically overloaded during periods of peak diurnal flow. equalization can reduce the maximum overflow rate to an acceptable level. A constant influent feed rate also avoids hydraulic disruptions in the clarifier created by sudden flow changes, especially those caused by additional wastewater lift pumps suddenly coming on line.

LaGrega and Keenan (2) investigated the effect of flow equalization at the 1.8 mgd Newark. New York Wastewater Treatment Plant. An existing aeration tank was temporarily converted to an equalization basin. They compared the performance of primary settling under marginal operating conditions, with and without equalization. The results are shown in Table 3-1.

It has been demonstrated (3) (4) that preaeration can significantly improve primary settling, as discussed in Chapter 8. Roe (3) concluded that preaeration preflocculates SS thereby improving their settling characteristics. Indications are that this benefit may be realized by aerated equalization basins. This benefit may be diminished when the equalized flow is centrifugally pumped to the primary clarifier, due to the shearing of the floc.

TABLE 3-1
EFFECT OF FLOW EQUALIZATION ON PRIMARY SETTLING
NEWARK, NEW YORK

	Normal Flow	Equalized Flow
Primary Influent SS, mg/l	136.7	128.0
Primary Effluent SS, mg/l	105.4	68.0
SS Removal in Primaries, percent	23	47

Note: Average flow slightly higher in unequalized portion of study.

3.2.2 Impact on Biological Treatment

As contrasted to primary treatment or other mainly physical processes where concentration damping is of minor benefit, biological treatment performance can benefit significantly from both concentration damping and flow smoothing. Concentration damping can protect biological processes from upset or failure from shock loadings of toxic or treatment inhibiting substances. Therefore, in-line equalization basins are preferred to side-line basins for biological treatment applications.

Improvement in effluent quality due to stabilized mass loading of BOD on biological systems treating normal domestic wastes has not been adequately demonstrated to date. It is expected that the effect will be significant where diurnal fluctuations in organic mass loadings are extreme. This situation may arise at a wastewater treatment plant receiving a high-strength industrial flow of short duration. Damping of flow and mass loading will also improve aeration tank performance where aeration equipment is marginal or inadequate in satisfying peak diurnal loading oxygen demands (5).

The optimum pH for bacterial growth lies between 6.5 and 7.5. In-line flow equalization can provide an effective means for maintaining a stabilized pH within this range.

Flow smoothing can be expected to improve final settling even more so than primary settling. In the activated sludge process, flow equalization has the added benefit of stabilizing the solids loading on the final clarifier. This has two ramifications:

1. The MLSS concentration can be increased thereby decreasing the F/M and increasing the SRT. This may result in an increased level of nitrification, and a decrease in biological sludge production. It may also improve the performance of a system operating at an excessively high daily peak F/M.

2. Diurnal fluctuations in the sludge blanket level will be reduced. This reduces the potential for solids being drawn over the weir by the higher velocities in the zone of the effluent weirs.

3.2.3 Miscellaneous Benefits

In chemical coagulation and precipitation systems using iron or aluminum salts, the quantity of chemical coagulant required is proportional to the mass of material to be precipitated. Damping of mass loadings with in-line equalization will improve chemical feed control and process reliability, and may reduce instrumentation complexity and costs.

Flow smoothing will reduce the surface area required and enhance the performance of tertiary filters. A constant feed rate will lead to more uniform solids loadings and filtration cycles.

The equalization basin provides an excellent point of return for recycled concentrated waste streams such as digester supernatant, sludge dewatering filtrate and polishing filter backwash.

Some BOD reduction is likely to occur in an aerated equalization basin. A 10 to 20 percent reduction has been suggested (6) for an in-line basin equalizing raw wastewater. However, the degree of reduction will depend upon the detention time in the basin, the aeration provided, wastewater temperature and other factors. For an existing treatment plant, a simple series of oxygen uptake studies on a representative sample of wastewater can determine the BOD reduction that will occur.

Roe (3) observed that preaeration may improve the treatability of raw wastewater by creating a positive oxidation-reduction potential, thereby reducing the degree of oxidation required in subsequent stages of treatment.

3.3 Determination of Equalization Requirements

The design of an equalization basin requires the evaluation and selection of a number of features as follows:

1. In-line versus side-line basins

2. Basin volume

3. Degree of compartmentalization

4. Type of construction - earthen, concrete or steel

5. Aeration and mixing equipment

6. Pumping and control concept

7. Location in treatment system.

The design decisions must be based on the nature and extent of the treatment processes used, the benefits desired, and local site conditions and constraints.

It may not be necessary to equalize the entire influent flow where high flow or concentration variations can be attributed to one source, such as an industry. In these cases the desired benefits can be achieved by simply equalizing the industrial flow. This can be accomplished through construction of an equalization basin at the industrial site or through in-house industrial process modifications to effect an equalized wastewater discharge.

3.3.1 Determination of Required Volume

Two methods are available for computing equalization volume requirements. One procedure is based on the characteristic diurnal flow pattern. In this case, the function of the basin is to store flows in excess of the average daily flow and to discharge them at times when the flow is less than the average. The required volume can be determined graphically through the construction of a hydrograph. The second procedure is based upon the mass loading pattern of a particular constituent. This method computes the volume required to dampen mass loading variations to within a preset acceptable range (7) (8).

Since the prime objective of flow equalization in wastewater treatment is to equalize flow, the determination of equalization volume should be based on the hydrograph. Once the volume has been determined for flow smoothing, the effect on concentration and mass load damping can be estimated. The required volumes for side-line and in-line basins will be identical. The hydrograph procedure is discussed below.

The first step in design involves the establishment of a diurnal flow pattern. Whenever possible, this should be based upon actual plant data. It is important to note that the diurnal pattern will vary from day to day, especially from weekday to weekend and also from month to month. The pattern selected must yield a large enough basin design to effectively equalize any reasonable dry weather diurnal flow. Figure 3-2 depicts a typical diurnal flow pattern. The average flow rate is 4.3 mgd. For purposes of this example, the average flow is used as the desired flow rate out of the equalization basin. The diurnal peak and minimum flow rate for this example are 1.7 and 0.45 times the average, respectively.

The next step involves the actual construction of the hydrograph. The hydrograph for this example is shown on Figure 3-3. The inflow mass diagram is plotted first. To do this, the hourly diurnal flows are converted to equivalent hourly volumes, and accumulated over the

FIGURE 3-2

RAW WASTEWATER FLOW AND BOD VARIATION BEFORE EQUALIZATION

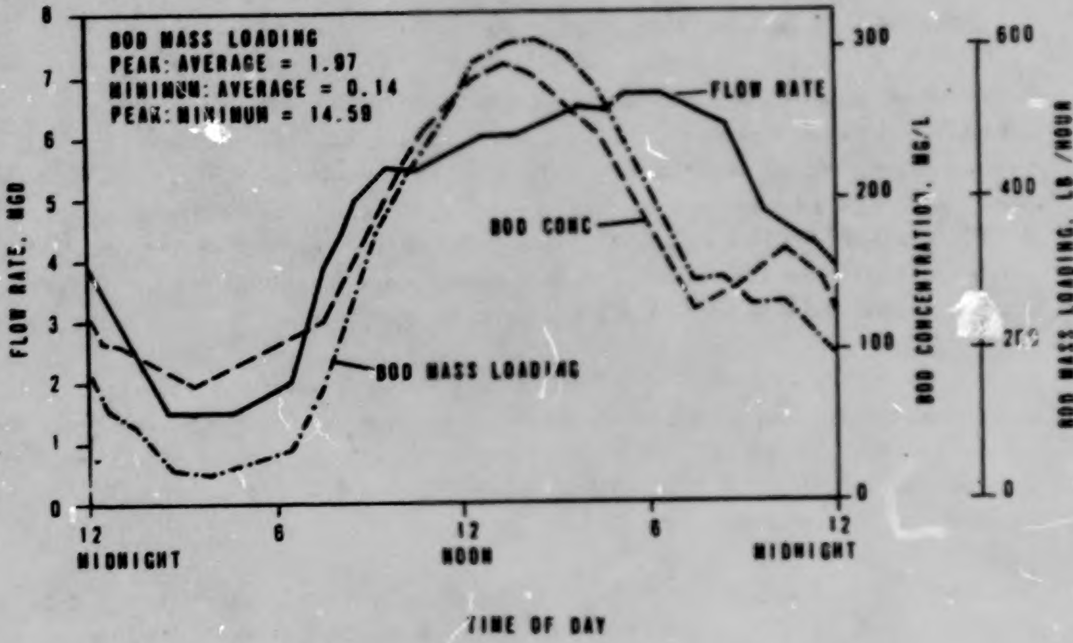
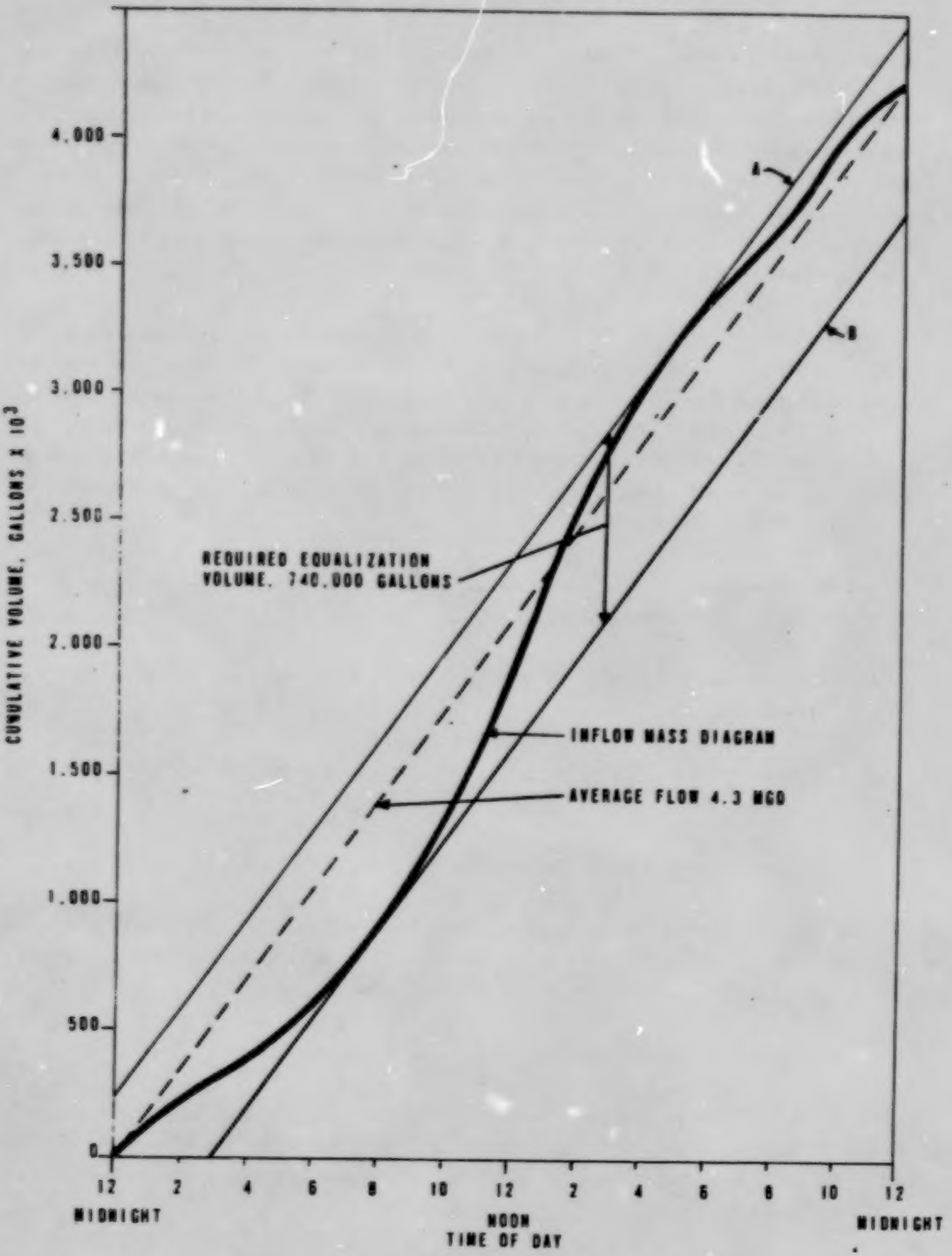


FIGURE 3-3
HYDROGRAPH FOR TYPICAL DIURNAL FLOW



24-hour day. A line is then drawn from the origin to the end point on the inflow mass diagram. The slope of this line actually represents the average flow for the day.

Enough tank volume must be provided to accumulate flows above the equalized flow rate. This normally requires a volume equivalent to 10 to 20 percent of the average daily dry weather flow. To determine this volume, the inflow mass diagram must be enveloped with two lines parallel to the average flow line and tangent to the extremities of the inflow mass diagram. These are shown as lines A and B on Figure 3-3. The required volume is represented by the vertical distance between these two lines. In this illustration, the required volume for equalization is 740,000 gallons, which represents approximately 17 percent of the average daily flow.

The physical interpretation of the hydrograph is simple. At 8:00 AM, the equalization basin is empty, as signified by the tangency of the inflow mass diagram with the bottom diagonal. At this point, plant flow begins to exceed the average flow rate and the tank begins to fill. This is represented by the divergence of the inflow mass diagram and the bottom diagonal. At 5:00 PM, the basin is full, as shown by the tangency of the inflow mass diagram with the top diagonal. Finally, the tank is drawn down from 5:00 PM to 8:00 AM on the following day, when the flow is below average.

The actual equalization basin volume must be greater than that obtained with the hydrograph for several reasons, including:

1. Continuous operation of aeration and mixing equipment will not allow complete drawdown.

2. Volume must be provided to accommodate anticipated concentrated plant recycle streams.

3. Some contingency should be provided for unforeseen changes in diurnal flow.

The final volume selected should include adequate consideration of the conditions listed above and will also depend on the basin geometry. For the example presented herein, a basin volume of approximately one million gallons is adequate.

3.3.2 Impact of Equalization on Diurnal Concentration Variation

At this point, it is appropriate to examine the impact of flow equalization on mass loading and concentrations. As previously mentioned, side-line equalization has a minimal effect on diurnal concentration variations. The following discussion is therefore limited to in-line basins.

An hourly concentration plot for raw wastewater BOD is plotted with the diurnal flow pattern on Figure 3-2. Note that low BOD concentrations occur at night with low flows, and high BOD concentrations occur during the daytime with high flows. This is a typical pattern for dry weather flows and BOD's. Because of this characteristic, the mass loading rate of raw wastewater BOD, shown on Figure 3-2, exhibits even greater fluctuations. If this wastewater is equalized in a one million gallon in-line basin, the equalized flow will exhibit the characteristics shown on Figure 3-4, provided:

1. The basin is designed to provide complete mixing.

2. There is no BOD reduction in the basin.

This damping effect would be similarly beneficial for all concentration variables including SS, nitrogen, phosphorus, and toxic constituents.

On Figure 3-4, the changes in BOD concentration are most pronounced during periods of minimum wastewater volume in the equalization tank. If desired, increased damping can be achieved by increasing the active volume of the tank, i.e., the volume in excess of that obtained from the hydrograph.

3.3.3 Basin Construction

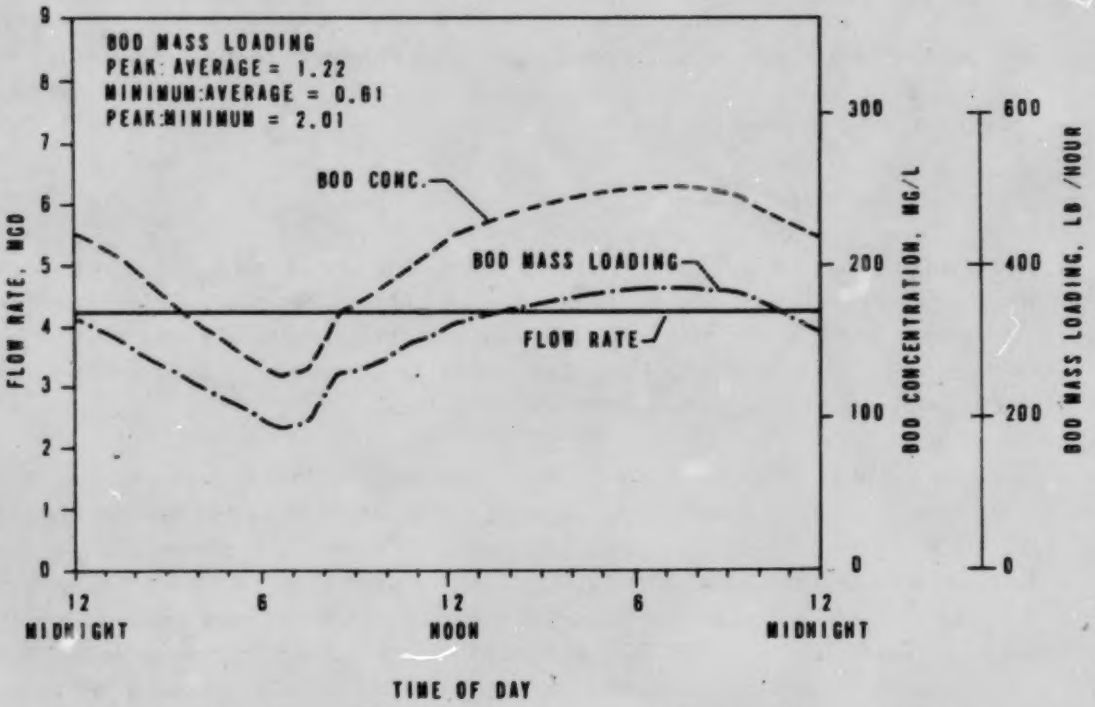
Equalization basins can be provided through the construction of new facilities or through the modification of existing facilities of sufficient volume. Equalization may be implemented with relative ease in an upgrading plan that calls for the abandonment of existing tankage. Facilities which may be suitable for conversion to equalization basins include aeration tanks, clarifiers, digesters and sludge lagoons.

New basins may be constructed of earth, concrete or steel. Earthen basins are generally the least expensive. They can normally be constructed with side slope varying between 3:1 and 2:1 horizontal to vertical, depending on the type of lining used. To prevent embankment failure in areas of high groundwater, drainage facilities should be provided for groundwater control. In large basins where a combination of aerator action and wind forces may cause the formation of large waves, precaution should be taken in design to prevent erosion. It is also customary to provide a concrete pad directly under the equalization basin aerator or mixer. The top of the dikes should be wide enough to ensure a stable embankment. For economy of construction, the top width of the dike should be sufficient to accommodate mechanical compaction equipment.

In-line basins should be designed to achieve complete mixing in order to optimize concentration damping. Elongated tank design enhances plug flow and should be avoided. Inlet and outlet configurations should be designed to prevent short-circuiting. Designs which discharge influent flow as close as possible to the basin mixers are preferred.

FIGURE 3-4

RAW WASTEWATER FLOW AND BOD VARIATION AFTER EQUALIZATION



To continue the previous illustration, an earthen basin has been selected for the equalization facility. A square plan has been chosen to effect optimum mixing. A section view of the basin with appropriate dimensions is shown on Figure 3-5. The volume requirement computed from the hydrograph is provided in the upper eight feet. Note that the minimum required operating depth lies above the minimum allowable aerator operating level.

3.3.4 Air and Mixing Requirements

The successful operation of both in-line and side-line basins requires proper mixing and aeration. Mixing equipment should be designed to blend the contents of the tank, and to prevent deposition of solids in the basin. To minimize mixing requirements, grit removal facilities should precede equalization basins wherever possible. Aeration is required to prevent the wastewater from becoming septic. Mixing requirements for blending a municipal wastewater having a SS concentration of approximately 200 mg/l range from 0.02 to 0.04 hp/1,000 gallons of storage. To maintain aerobic conditions, air should be supplied at a rate of 1.25 to 2.0 cfm/1,000 gallons of storage (9).

Mechanical aerators are one method of providing both mixing and aeration. The oxygen transfer capabilities of mechanical aerators operating in tap water under standard conditions vary from 3 to 4 lb O_2/hp-hr. Baffling may be necessary to ensure proper mixing, particularly with a circular tank configuration. Minimum operating levels for floating aerators generally exceed five feet, and vary with the horsepower and design of the unit. Low level shutoff controls should be provided to protect the unit. The horsepower requirements to prevent deposition of solids in the basin may greatly exceed the horsepower needed for blending and oxygen transfer. In such cases, it may be more economical to install mixing equipment to keep the solids in suspension and furnish the air requirements through a diffused air system, or by mounting a surface aerator blade on the mixer.

It should be cautioned that other factors including maximum operating depth and basin configuration affect the size, type, quantity and placement of the aeration equipment. In all cases, the manufacturer should be consulted.

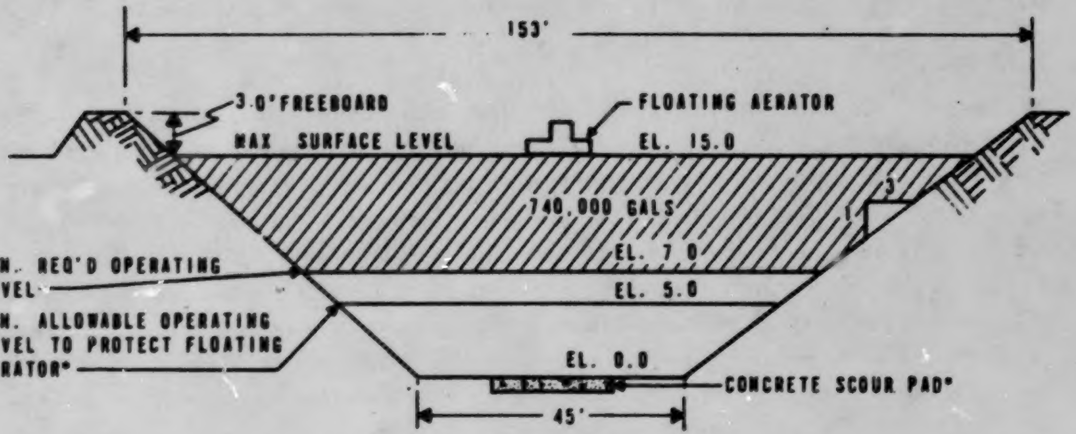
3.3.5 Pump and Pump Control Systems

Flow equalization imposes an additional head requirement within the treatment plant. As a minimum, this head is equal to the sum of the dynamic losses and the normal surface level variation. Additional head may be required if the basin is to be dewatered to a downstream location. It may be possible to dewater the basin upstream (e.g., ahead of raw wastewater pumps) by gravity.

Normally, the head requirement cannot be fulfilled by gravity, thereby requiring pumping facilities. The pumping may precede or follow equalization. In some cases pumping of both

FIGURE 3-5

EARTHEN EQUALIZATION BASIN



VOLUMES:

EL. 0.0 TO EL. 7.0 APPROXIMATELY 260,000 GAL.
EL. 7.0 TO EL. 15.0 APPROXIMATELY 740,000 GAL.
TOTAL VOLUME = 1,000,000 GAL.

*THESE DIMENSIONS WILL VARY WITH AERATOR DESIGN AND HORSEPOWER raw and equalized flows will be required. Influent pumping will require larger capacity pumps to satisfy diurnal peaks.

Gravity discharge from equalization will require an automatically controlled flow regulating device.

A flow measuring device is required downstream of the basin to monitor the equalized flow. Instrumentation should be provided to control the preselected equalization rate by automatic adjustment of the basin effluent pumps or flow-regulating device.

3.3.6 Miscellaneous Considerations

The following features are considered to be desirable for the design of the equalization facility:

1. Equalization should be preceded if possible with screening and grit removal to prevent grit deposition and rag fouling of equipment in the basin.

2. Surface aerators should be fitted with legs to support and protect the units when the tank is dewatered.

3. Facilities should be provided to flush solids and grease accumulations from the basin walls.

4. A high-water level takeoff should be provided for withdrawing floating material and foam.

5. An emergency overflow should be provided.

3.4 Costs

The development of alternatives for any plant upgrading program should include at least one which incorporates flow equalization. In all cases, the added cost of flow equalization must be measured against (1) the savings in cost of modifying downstream processes to accept diurnal variations and (2) the improved performance that can be achieved by operating downstream processes under relatively constant loading conditions.

The cost of flow equalization will vary considerably from one application to another, depending on the basin size, construction selected, mixing and aeration requirements, availability of land, location of facility, and pumping requirements. Some judgment must be made on the distribution of pumping costs. Pumping costs for an equalization basin used to upgrade existing facilities should be charged to the basin.

Capital costs for equalization facilities have been estimated by Smith, et al. (10) and are listed in Table 3-2. The costs for earthen basins include plastic liner and floating mechanical aerators. The costs for the concrete basins include diffused aeration facilities. Pumping costs are based on the construction of a separate equalization basin effluent pumping station. The costs were developed in conjunction with activated sludge treatment system designs and therefore include a proportional amount of the engineering fees and interest during construction.

TABLE 3-2
COST OF EQUALIZATION FACILITIES
(EPA INDEX 175)

		Earthen Basin		Concrete Basin	
Plant Size mgd	Basin Size mil gal	With Pumping	Without Pumping	With Pumping	Without Pumping
1	0.32	$124.000	$ 72,300	$175.000	$124.000
3	0.88	170.000	84,000	333.000	247,000
10	2.40	318.000	134.000	779.000	595.000

The construction cost for the earthen equalization basin on Figure 3-5 is estimated at $80,000. The cost includes excavation, plastic liner, sand subbase, concrete scour pad, dike fill, underdrain and a 40-hp floating aerator. The costs do not provide for pumping costs, land costs, engineering and legal fees, nor interest during construction.

3.5 Performance and Case Histories

Little full-scale operating data are currently available to compare the performance of wastewater treatment plants with and without flow equalization. However, an increasing number of plant designs are incorporating the use of equalization facilities for upgrading existing plants and construction of new plants. The following case histories are presented as examples of equalization basin design.

3.5.1 Ypsilanti Township, Michigan

A flow equalization project at the Ypsilanti Township Sewage Treatment Plant is currently under way. The treatment facility consists of two adjacent activated sludge plants recently upgraded from 7.0 mgd to treat a total flow of 9.0 mgd. Two 350,000-gallon digesters have been converted to equalization tanks. Data will be collected over a two-year study period for each plant. The flow will be equalized to one plant the first year while background data is collected for the remaining plant. The situation will be reversed the second year, with the flow being equalized to the second plant while unequalized flow performance data are collected on the first plant. Comparison of these data will be made to determine the beneficial effects of flow equalization on each plant.

3.5.2 Fond du Lac, Wisconsin

This case illustrates a situation in which only a portion of the flow is equalized. The City of Fond du Lac, Wisconsin, presently employs a single-stage trickling filter plant to treat combined municipal-industrial wastes. Placed in operation in 1950, the plant was designed to treat an ultimate dry weather flow of 8 mgd and a BOD loading of 12,500 lb/day. The facility is presently treating an average of 7.1 mgd with a BOD loading of 24,000 lb/day, and hence is organically overloaded. This condition is aggravated by the fact that the waste discharges from a major industrial contributor (a tannery) are presently concentrated during daylight hours. The tannery discharges wastes to the treatment plant via a separate force main. It accounts for about 35 percent of the BOD and 50 percent of the SS into the plant, and about 15 percent of the influent flow, resulting in a widely fluctuating BOD and SS diurnal load profile.

The wide fluctuations in organic loading are resulting in reduced performance of the trickling filters. This, in conjunction with the advent of more stringent treatment standards, has rendered this facility inadequate. Plans are presently under way to upgrade the treatment plant.

This case represents an ideal situation for employing partial equalization in the upgrading scheme. The volume of the wastes from the tannery is relatively small compared to the total volume of flow received at the plant, whereas the organic contribution is significant. Therefore, a relatively small volume equalization tank is all that is required to attain effective organic load equalization. In addition, because the tannery discharges to the treatment plant via a separate force main, equalization may be accomplished at the treatment plant site. The effect of equalizing the tannery flow over 24 hours is illustrated on Figure 3-6.

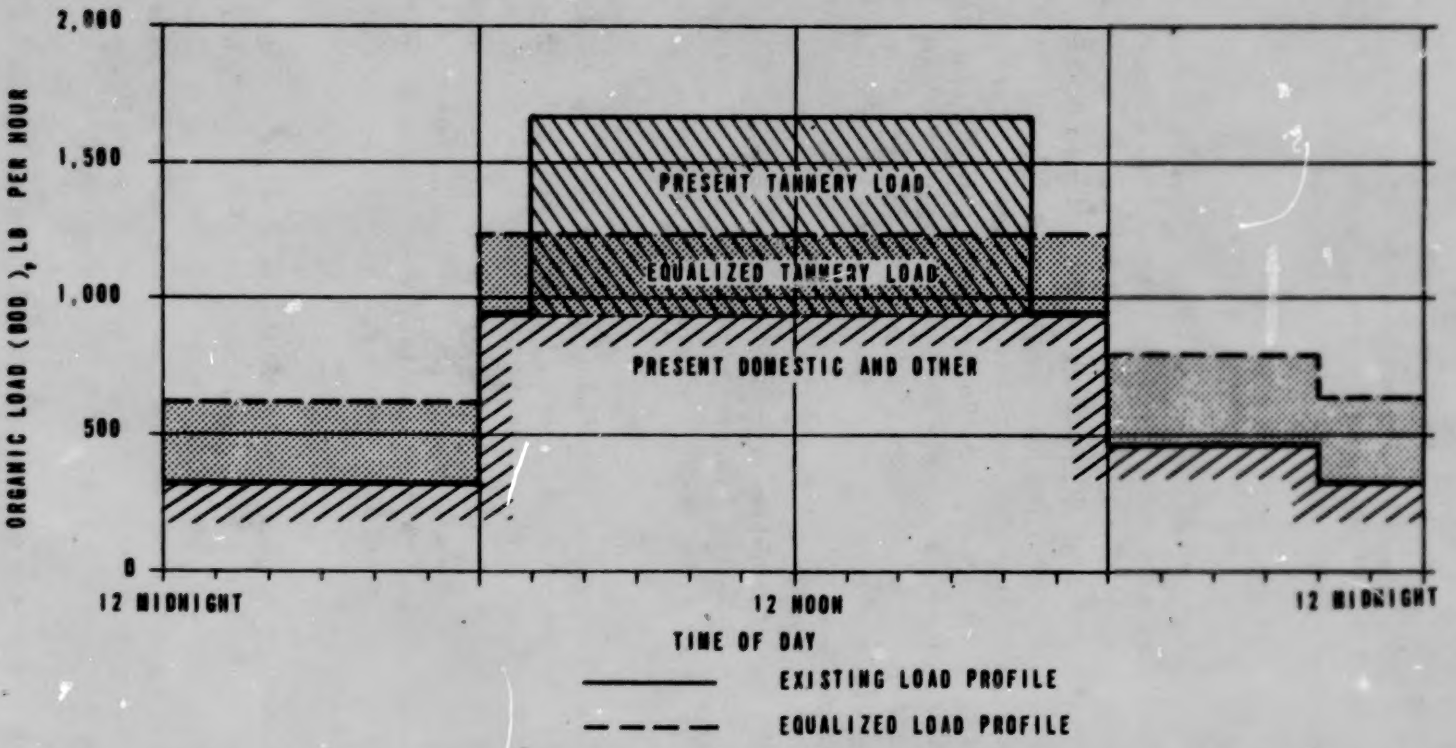
Located at the plant site are six abandoned square anaerobic digesters, each measuring 50 feet by 50 feet by 17.5 feet deep. Four of the units have fixed covers and two have floating covers. The utilization of these tanks for equalizing the tannery flow was investigated. The investigations indicate that the four fixed cover tanks would be adequate for equalization for all but a few days each year when the use of the two additional tanks would be necessary because of high flows or maintenance.

The conversion of the abandoned digesters to equalization tanks entails complete modification of the four fixed covered tanks and only minimal modification of the two tanks which have floating covers. The four fixed covered tanks would each require the

FIGURE 3-6

EFFECT OF TANNERY FLOW EQUALIZATION

T4.1.20



installation of a mechanical mixer to maintain solids in suspension, including structural modifications in order to support the mixers. A ventilation system would be required for the covered tanks to ensure the safety of plant personnel who may enter the tanks for purposes of inspection or maintenance. Minor structural repairs and waterproofing of all six tanks would be necessary to ensure their structural integrity and watertightness. The two floating covers would be removed and the pipe gallery would be converted to a pump station.

The cost for converting these units to equalization tanks is estimated at approximately $440,000. This cost includes process pumping equipment and piping, four mechanical mixers, tank ventilation system, instrumentation, electrical work, structural renovations and alterations, and engineering fees.

At present, additional studies are under way to evaluate the feasibility of equalization of tannery wastes at the tannery in lieu of equalizing these wastes at the plant site.

3.5.3 Walled Lake – Novi, Michigan

The Walled Lake-Novi Wastewater Treatment Plant is a new 2.1 mgd facility employing side-line flow equalization. The treatment plant was placed into operation in 1971. It was designed to meet stringent effluent quality standards, including (1) a summertime monthly average BOD_{20} of 8 mg/l, (2) a wintertime monthly average BOD_{20} of 15 mg/l, and (3) 10 mg/l of SS. The facility utilizes the activated sludge process followed by multimedia tertiary filters. Ferrous chloride and lime are added ahead of aeration for phosphorus removal. Sludge is processed by aerobic digestion, and dewatered on sludge drying beds. A schematic diagram of this facility is shown on Figure 3-7.

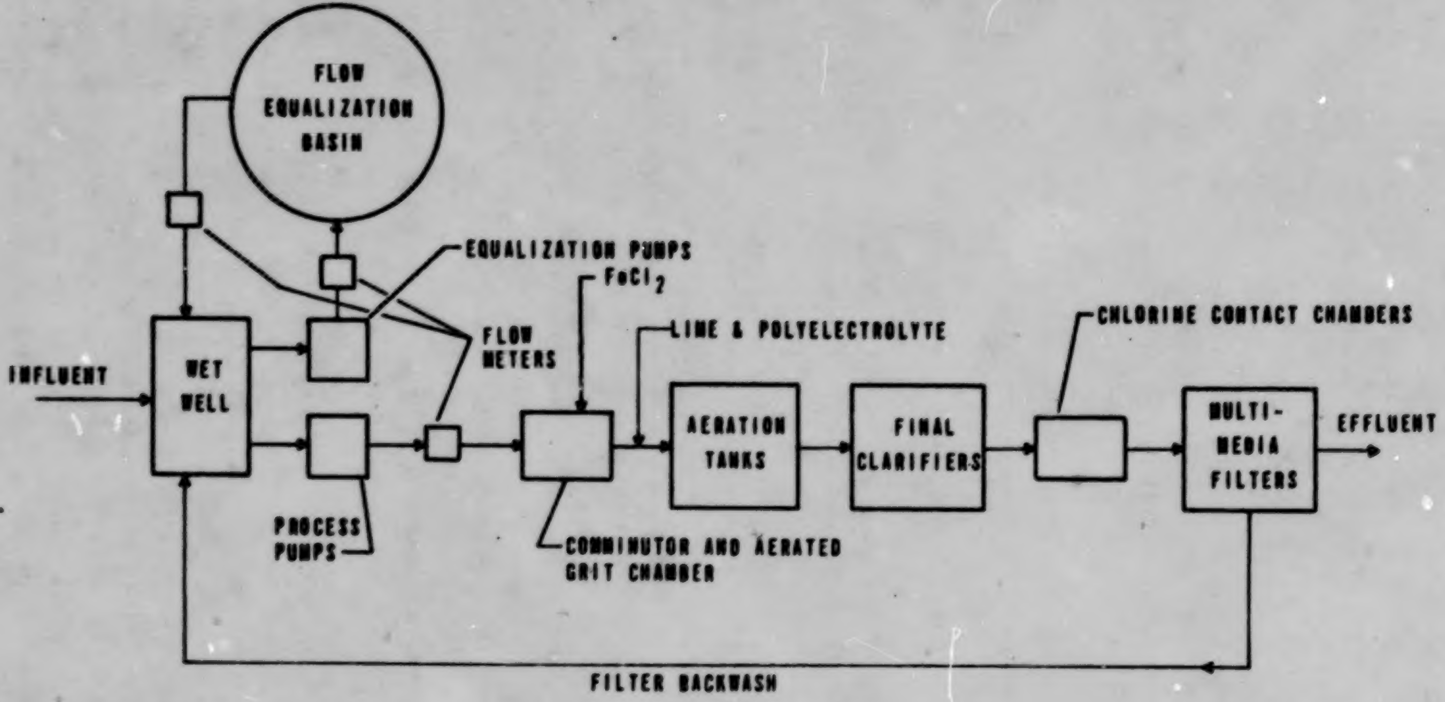
A major factor in the decision to employ flow equalization was the desire to load the tertiary filters at a constant rate. The equalization facility consists of a 315,000-gallon concrete tank which is equivalent in volume to 15 percent of the design flow. The tank is 15 feet deep and 60 feet in diameter. Aeration and mixing are provided by a diffused air system with a capacity of 2 cfm/1,000 gallons of storage. Chlorination is provided for odor control. A sludge scraper is installed to prevent consolidation of the sludge.

The equalization facility is operated as follows (11). The process pumping rate is preset on the pump controller to deliver the estimated average flow to the treatment processes. The flow delivered by these pumps is monitored by a flowmeter which automatically adjusts the speed of the pumps to maintain the average flow rate. When the raw wastewater flow to the wet well exceeds the preset average, the wet well level rises, thereby actuating variable speed equalization pumps which deliver the excess flow to the equalization basin. When the inflow to the wet well is less than the average, the wet well level falls and an automatic equalization basin effluent control valve opens. The valve releases enough wastewater to the wet well to reestablish the average flow rate through the plant. Since this is a new plant as opposed to

FIGURE 3-7

WALLED LAKE-NOVI WASTEWATER TREATMENT PLANT

T4.1.22



an upgraded plant, no comparative data exist. However, the treatment facility is typically producing a highly treated effluent, with BOD and SS less than 4 mg/l and 5 mg/l, respectively (9).

3.5.4 Novi Interceptor Retention Basin, Oakland County, Michigan

This case (12) illustrates the utilization of an equalization basin within the wastewater collection system.

A portion of the wastewater collection system for the City of Novi, Michigan, discharges to the existing Wayne County Rouge Valley Interceptor System. Due to the existing connected load on the Wayne County system, Novi's wastewater discharge to the interceptor system is limited to a maximum flow rate of 4 cfs. This rate was matched by the existing maximum diurnal flows from the city. In order that additional population could be served, it was decided to equalize wastewater flows to the interceptor system. By discharging to the interceptor continuously at an average rate of flow, the total wastewater flows from the City of Novi to the Wayne County Rouge Valley Interceptor system could be increased by a factor of 2.6.

An 87,000-cu ft concrete basin was constructed for equalizing flows. The tank has a diameter of 92 feet and a depth of 10.5 feet. Aeration and mixing are provided by a diffused air system with a capacity to deliver 2 cfm/1,000 gallons of storage.

A manhole located upstream of the equalization basin intercepts the flow in the existing Novi trunk sewer. The intercepted wastewater flows into a weir structure which allows a maximum of 4 cfs to discharge into the Wayne County system. The wastewater in excess of the preset average overflows into a wet well where it is pumped to the equalization basin. When flows in the interceptor fall below the preset average, a flow control meter generates a signal opening an automatic valve on the effluent line of the basin, allowing stored wastewater to augment the flow.

3.6 References

1. Click, C.N., *The Feasibility of Flow Smoothing Stations in Municipal Sewage Systems.* U. S. EPA Project No. 11010 FDI, Contract No. 14-12-935 (August, 1972).

2. LaGrega, M.D., and Keenan, J.D., *Effects of Equalizing Sewage Flow.* Presented at the 45th Annual Conference of the Water Pollution Control Federation, Atlanta, Ga. (October, 1972).

3. Roe, F.C., *Preaeration and Air Flocculation.* Sewage Works Journal, 23, No. 2, pp. 127-140 (1951).

4. Seidel, H.F., and Baumann, E.R., *Effect of Preaeration on the Primary Treatment of Sewage*. JWPCF, 33, No. 4, pp. 339-355 (1961).

5. Boon, A.G., and Burgess, D.R., *Effects of Diurnal Variations in Flow of Settled Sewage on the Performance of High Rate Activated-Sludge Plants*. Water Pollution Control, pp. 493-522 (1972).

6. Ames, Iowa: Private communication with Dr. E. Robert Baumann, Iowa State University (December 11, 1973).

7. Bradley, P.R., and Oldshue, J.Y., *The Role of Mixing in Equalization*. Presented at the 45th Annual Conference of the Water Pollution Control Federation, Atlanta, Ga. (October, 1972).

8. Wallace, A.T., *Analysis of Equalization Basins*. Journal of the Sanitary Engineering Division, ASCE, SA6, pp. 1161-1171 (1968).

9. Smith, J.M., Masse, A.N., and Feige, W.A., *Upgrading Existing Wastewater Treatment Plants*. Technology Transfer Design Seminar. Presented at Vanderbilt University (September 18, 1972).

10. Smith, R., Eilers, R.G., and Hall, E.D., *Design and Simulation of Equalization Basins*. U.S. Environmental Protection Agency, Internal Publication (February, 1973).

11. Johnson & Anderson, Inc., *Operation and Maintenance Manual for Wastewater Treatment Plant, Walled Lake Arm, Huron-Rouge Sewage Disposal System*. Oakland County D.P.W., Oakland Co., Michigan (June, 1973).

12. Johnson & Anderson, Inc., *Operation and Maintenance Manual for Sewage Retention Reservoir, Novi Trunk Extension No. 1, Huron-Rouge Sewage Disposal System*. Oakland County D.P.W., Oakland Co., Michigan (September, 1973).

Design Manual for Upgrading Existing Wastewater Treatment Plants, Technology Transfer, Environmental Protection Agency, Cincinnati, OH (1974).

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 4: Pre/Primary Treatment

Lesson 2: Primary Treatment

Lesson 2 of 2 Recommended Time: 50 minutes

Purpose: This lesson applies the *Process of Troubleshooting* to primary treatment process operations and identifies eight common operational deficiencies in primary treatment. Effective primary treatment is essential to overall plant operations because primary treatment is an inexpensive method for removal of suspended solids from wastewater. Efficient primary treatment can substantially reduce the loads applied to downstream processes. Strategies used to control primary sludge pumping have a direct impact on performance of solids handling processes.

Trainee Entry Level Behavior: Trainees should have completed Unit of Instruction 1: *Overview* and Unit of Instruction 2: *Elements of Troubleshooting* before beginning this lesson. Although not a mandatory prerequisite to this lesson, it is desirable that trainees complete Unit of Instruction 3, *Sewer Use Control* and Lesson 1 of this unit before beginning the lesson on primary treatment.

Training Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. From memory, apply the *Process of Troubleshooting* to identify and correct operational problems in primary treatment.
2. From memory, list at least five common operational problems in primary treatment, describe how each is identified, list the alternative causes for each problem and recommend appropriate corrective action for each problem.
3. Using references and class notes, describe procedures for and list criteria for the evaluation of primary treatment process operations.

Instructional Approach: Illustrated lecture with class discussion and problem solving. It is recommended that the instructor follow the lesson outline provided.

Lesson Schedule: The 50 minutes allocated to this lesson should be scheduled as follows:

TIME	ACTIVITY
0 - 5 minutes	Initiating the Process of Troubleshooting
5 - 10 minutes	Laboratory Tests
10 - 45 minutes	Troubleshooting Problems in Primary Treatment
45 - 50 minutes	Summary and Discussion

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, page T2.2.8, "The Process of Troubleshooting."
2. *Trainee Notebook*, page T4.2.1-T4.2.2, "Information Regarding Normal Operations of Primary Clarification."
3. *Trainee Notebook*, page T4.2.3, "References"
4. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 42-54, "Primary Clarification."

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 4.2.1 - 4.2.16.
2. Slides 179.2/4.2.1 - 179.2/4.2.34.
3. *Instructor Notebook*, Unit 2: *Elements of Troubleshooting.*

Instructor Materials Recommended for Development: A documented primary treatment troubleshooting case history from the instructor's experience which is structured for solution by the class to apply the Process of Troubleshooting. Such a case history could be used to illustrate the application of the *Process of Troubleshooting* to primary treatment and be used to replace the general application included in this lesson.

Additional Instructor References:

1. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA/430/9-78-001, Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (1978).

2. *Inspector Guide for Evaluation of Municipal Wastewater Treatment Plants*, EPA/430/9-79-010, Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (1979).

3. *Process Design Manual for Upgrading Existing Wastewater Treatment Plants*, Environmental Protection Agency, Technology Transfer, Cincinnati, OH (1974).

4. *Manual of Instruction for Sewage Treatment Plant Operators*, New York State Department of Health, Albany, NY.

5. *Operation of Wastewater Treatment Plants, A Home Study Course*, University of California at Sacramento, Sacramento, CA (1970).

6. *Operation of Wastewater Treatment Plants*, MOP 11, Water Pollution Control Federation, Washington, D.C. (1976).

7. *Manual of Wastewater Operations*, Texas Water Utilities Association, Austin, TX (1971).

Classroom Set-Up: As specified in the Instructor Overview to the Unit, *Instructor Notebook*, page 4.2.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	Review Unit of Instruction 2, *Elements of Troubleshooting*, and relate lesson to the steps in the Process of Troubleshooting. Use Slide 179.2/4.2.1 Slide 179.2/4.2.1 is a blank used to blacken screen.
I. Initiating the Process of Troubleshooting (5 min.)	
A. Inform class that this lesson will apply the Process of Troubleshooting to primary clarification processes.	Refer class to *Trainee Notebook*, page T2.2.8, "The Process of Troubleshooting.
B. First steps in Troubleshooting	Use Slide 179.2/4.2.2
1. Use Slide 179.2/4.2.2 to key class discussion to identify information to be obtained from records and initial plant visits.	Slide 179.2/4.2.2 reads: "Initial Steps in the Process of Troubleshooting * Review known information * Visit plant: meet, listen, observe and review"
2. Following lists some of the items to be identified. Use Slide 179.2/4.2.3 to guide summary of class responses.	Use Slide 179.2/4.2.3 Slide 179.2/4.2.3 reads:
a. Design data (1) Processes (2) Dimensions (3) Loadings	"Learn How the Plant Normally Operates * Flows, load and balance * Removal efficiency * Sludge Handling * Maintenance and condition"
b. Raw waste characteristics (1) Flows (2) Composition	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
c. Operating records (1) NPDES Monitoring data (2) Any available data on individual unit operations.	
3. Data sources include design file, permit files, O & M manual, operators, personal observations, etc.	
4. Observations of normal primary clarifier operations. (Use series of six slides to illustrate key points for evaluating primary clarifier operations.)	
a. Are flows equally distributed to all units?	Use Slide 179.2/4.2.4 Slide 179.2/4.2.4 is a photograph showing good flow splitter box with equal flows going to each channel.
b. Are overflow weirs level and clean?	Use Slide 179.2/4.2.5 Slide 179.2/4.2.5 is a photograph showing operator hosing down weirs.
c. Are routine inspections and preventive maintenance performed? Is the equipment in good repair?	Use Slide 179.2/4.2.6 Slide 179.2/4.2.6 is a photograph showing an operator removing primary clarifier chain housing to inspect or service flight chain drives.
d. Does plant normally operate up to design efficiency for suspended solids removal (50 - 70%)?	Use Slide 179.2/4.2.7 Slide 179.2/4.2.7 is a primary sedimentation efficiency graph showing % solids removal as a function of settling time.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
e. Is BOD removal in normal ranges (35-40%)?	Use Slide 179.2/4.2.8 Slide 179.2/4.2.8 is a primary sedimentation efficiency graph showing % BOD removal as a function of settling time.
f. Do the clarifiers provide efficient scum removal? Point out the following on this slide: (1) Scum collector (2) Scum baffle (3) Heavy scum accumulation behind scum baffle (4) Good supernate (effluent) (5) Possible problem because scum and grease are not being efficiently removed from tank	Use Slide 179.2/4.2.9 Slide 179.2/4.2.9 is a photograph showing primary clarifier with scum baffle and skimming device. Scum is being retained but with heavy accumulation inside scum baffle.
5. Expected primary clarifier performance	
a. Refer class to *Trainee Notebook*, page T4.2.1, "Information Regarding Normal Operation of Primary Clarification."	Refer to *Trainee Notebook*, page T4.2.1, "Information Regarding Normal Operation of Primary Clarification."
b. Briefly review characteristics of municipal sewage.	
c. Briefly review expected removals in primary clarification and discuss impact on downstream units if primary clarifier does not perform efficiently: (1) Added organic and solids load on secondary system. (2) Poor concentration of primary sludge fed to solids handling units. (3) Grease carry-over will accumulate in other units and add to load.	

LESSON OUTLINE

d. Use above to stress importance of primary clarification to total system efficiency. Primary treatment is very low cost removal of BOD and TSS when compared to secondary treatment costs in mechanical plant.

II. Laboratory Tests for Process Control and for Troubleshooting (5 min.)

A. Use Slide 179.2/4.2.10 to highlight "Analyze and Learn" steps in the Process of Troubleshooting (Refer to Unit of Instruction 2: *Elements of Troubleshooting*, Lesson 2 for a discussion of the Process of Troubleshooting.)

B. Use Slide 179.2/4.2.11 to summarize laboratory data needed to evaluate primary clarifiers.

1. Solids - measure efficiency
   100% removal settleable solids
   50-70% removal suspended solids

2. BOD - Expect 35-40% removal. BOD increase across primary tank, may suspect:

   a. Anaerobic decomposition in tank

   b. Plant internal recycles adding to load, e.g.

      (1) Digester supernate
      (2) Filtrates
      (3) Thickener subnate or supernate

3. pH - use similar to 2.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/4.2.10

Slide 179.2/4.2.10 reads:

"The Process of Troubleshooting - Analyze and Learn

* Determine data needs
* Analyze, sample and test
* Process test, modify process and analyze"

Use Slide 179.2/4.2.11

Slide 179.2/4.2.11 reads:

"Lab Tests - Primary Treatment Process Control and Trouble-Shooting

* Solids
  *Settleable and suspended
  *Total
* BOD
* pH
* Special Tests"

LESSON OUTLINE

4. Special tests are covered on next slide.

C. Use Slide 179.2/4.2.12 to summarize other tests which may be run to evaluate or improve primary clarification.

   1. Jar testing for chemical coagulation or precipitation is discussed in detail in Unit of Instruction 9, *Chemical Additions*.

   2. Dissolved oxygen to check for anaerobic conditions.

   3. Heavy metals

      a. Industrial wastes
      b. Chemical precipitation

D. Use Slide 179.2/4.2.13 to illustrate use of Imhoff cone for settleable solids test. Stress the following:

   1. Simple test for evaluating primary clarifier efficiency, particularly useful to detect hydraulic problems (short circuiting, turbulence, bottom scour).

   2. Ask class about the significance of the white solids:

      Answer: Diary waste (whey) was large contributor to this system.

III. Troubleshooting Problem in Primary Treatment (35 minutes)

   A. Use Slide 179.2/4.2.14 to summarize purposes for analysis of data:

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/4.2.12

Slide 179.2/4.2.12 reads:

"Special Tests Useful in Trouble-shooting Primary Treatment

- * Jar test for chemical coagulation
- * Dissolved oxygen
- * Heavy metals"

Use Slide 179.2/4.2.13

Slide 179.2/4.2.13 is a photograph showing a single Imhoff cone with white settled solids.

Use Slide 179.2/4.2.14

Slide 179.2/4.2.14 reads:

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
1. Identify all possible causes for problems and prioritize.	"Problem Analysis in Primary Treatment
2. List all possible corrective actions, priorize and implement preferred solution.	Troubleshooting for Problem * Causes
3. Devise operational programs to prevent recurrence of problems.	* Alternative corrections * Prevention"
B. Use Slides 179.2/4.2.15 and 179.2/4.2.16 to list common problems in primary clarification.	
1. Use Slide 179.2/4.2.15 and leave on for a few minutes for class to note list of problems.	Use Slide 179.2/4.2.15 Slide 179.2/4.2.15 reads: "Common Problems - Primary Treatment * Floating sludge * Septic wastewater * Growths on weirs * Sediment in inlet channels"
2. Use Slide 179.2/4.2.16 and give class time to note list of problems.	Use Slide 179.2/4.2.16 Slide 179.2/4.2.16 reads: "More Common Problems - Primary Treatment * Surging or intermittent flow * Scraper or shear pin failure * Sludge removal from hopper * Excessive corrosion"
3. Inform class that we will now look at problems in more detail.	
C. Floating Sludge	Use Slide 179.2/4.2.17

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
1. Use Slides 179.2/4.2.17 and 179.2/4.2.18 to illustrate problems.	Slide 179.2/4.2.17 is a photograph showing light colored floating sludge on primary clarifier. Use Slide 179.2/4.2.18 Slide 179.2/4.2.18 is a photograph showing black floating sludge on primary clarifier.
2. Show Slide 179.2/4.2.19 and have trainee work groups develop answers to the following questions:	Use Slide 179.2/4.2.19 Slide 179.2/4.2.19 reads:
a. Causes of floating sludge?	"Floating Sludge
b. Alternative corrections?	* Causes? * Alternative corrections? * Prevention?"
c. Prevention?	
3. Following points should be covered in the discussion:	
a. Cause: Sludge decomposing in tank and buoyed to surface.	
b. Prevention: (1) Remove sludge more completely or frequently.	
c. Correction: (1) Operate mechanical scrapers for longer periods or continuously. (2) Repair or replace broken or warped wooden flights. (3) Remove sludge from hoppers more completely by continuous withdrawal or pumping for longer periods at slower rates. (4) Where sludge clings to inclined surfaces, remove by	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
squeegeeing solids to sludge hopper.	
D. Septic Wastewater	
1. Have trainee work groups respond to questions on Slide 179.2/4.2.20.	Use Slide 179.2/4.2.20 Slide 179.2/4.2.20 reads: "Septic Wastewater - Black and Odorous * Causes? * Alternative corrections? * Prevention?"
2. The following points should be covered in the discussion:	
a. Cause: flat grades in collection system, improper operation of lift stations, industrial waste discharges, shock loads from commercial haulers, digester supernatant or improper solids withdrawal from unit.	
b. Prevention: (1) Maintain velocities in collection lines by flushing program. (2) Inspect lift stations daily for proper operation. (3) Industrial plants and commercial haulers should provide pretreatment of strong wastes. (4) Digester supernatant should receive further treatment before entering head of plant. (5) Regular program of withdrawing solids from unit.	
c. Correction: (1) Pre-aerate types of wastes	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
listed above (2) Chlorinate in collection system ahead of treatment plant or ahead of sedimentation tank to delay or reduce decomposition of wastewater. (3) Improve hydraulics of wastewater system to reduce accumulations of solids. (4) Digester supernate: cure (a) Correct or improve sludge digestion to produce improved quality supernate. (b) Reduce rate of withdrawal of supernatant to sedimentation tank. (c) Pre-settle or elutriate the supernatant. (d) Select better quality of supernatant from another zone or delay withdrawal until quality improves. (e) Discharge a portion or all of supernatant, until quality improves, to other points such as: sludge drying bed or supernatant aeration tank. (5) Systematic program of sludge removal from sedimentation unit.	
3. Use Slide 179.2/4.2.21 to illustrate septic sludge problem.	Use Slide 179.2/4.2.21 Slide 179.2/4.2.21 is a photograph showing thick black sludge which resulted from sludge being left in primary clarifier overnight.
4. Use Slide 179.2/4.2.22 to illustrate covered primary clarifiers used for odor control in warm climates.	Use Slide 179.2/4.2.22 Slide 179.2/4.2.22 is a photograph of covered primary clarifiers.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
5. Use Slide 179.2/4.2.23 to illustrate effects of inadequate sludge drawdown in primary clarifier a. Sludge blanket accumulation b. Turns septic c. Sludge floating d. Odors form	Use Slide 179.2/4.2.23 Slide 179.2/4.2.23 is a schematic diagram showing sludge blanket accumulation in primary clarifier with subsequent floating sludge. Problem is caused by inadequate sludge drawdown.
E. Broken flights, chains or shear pins	Use Slide 179.2/4.2.24
1. Use Slide 179.2/4.2.24 to illustrate the problem.	Slide 179.2.4.2.24 is a photograph showing rectangular primary clarifier with broken flights and improperly maintained scum baffle.
2. Use Slide 179.2/4.2.25 and have class respond to questions.	Use Slide 179.2/4.2.25 Slide 179.2/4.2.25 reads: "Broken Scraper Chains or Shear Pin Failures * Causes? * Alternative corrections? * Prevention?"
3. The following should be covered in the discussion: a. Cause: Excessive load on sludge scraper. b. Prevention: (1) Periodically dewater tank and examine all metal parts for defects and wear. (2) Replace defective and worn parts. c. Correction:	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
(1) Operate collector mechanism continuously or for longer periods and/or pump sludge more often.	
(2) Operate grit chamber or reduce entrance of grit to tank if grit accumulation is substantial.	
(3) Remove or break up ice formation on walls and surfaces.	
F. Discussion of Other Primary Treatment Problems	
1. Briefly review Troubleshooting Guide.	Refer class to page 50, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities.*
2. Portrayal of other problems	
a. Sediment and sludge in inlet channel.	Use Slide 179.2/4.2.26 Slide 179.2/4.2.26 is a photograph showing thick sludge accumulation in entrance channel.
b. Surging flow. Substantial solids overflow due to poor pump programming causing hydraulic and organic overload.	Use Slide 179.2/4.2.27 Slide 179.2/4.2.27 is a photograph showing primary clarifier solids washout from a hydraulic surge.
c. Sludge removal from hopper. Sectional diagram shows solids buildup. Coning may occur when pumping rates are high. The high pumping rates "suck" a hole in the sludge blanket. Water, not sludge, is then pumped. Best corrected by more frequent sludge pumping at lower rates.	Use Slide 179.2/4.2.28 Slide 179.2/4.2.28 is a schematic diagram illustrating coning.
d. Excessive corrosion. Inoperative scum removal apparatus caused by long term corrosion, improper O & M.	Use Slide 179.2/4.2.29 Slide 179.2/4.2.29 shows corroded scum collector which is out of service with thick scum accumulation. Cake is about 6" thick and solidified.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
IV. Summary and Discussion (5 min.)	
A. Troubleshooting Actions Use Slide 179.2/4.2.30 and briefly discuss types of actions which might be used in primary treatment troubleshooting. 1. Process and operational changes 2. Equipment repair 3. Cleaning and maintenance 4. Chemical additions	Use Slide 179.2/4.2.30 Slide 179.2/4.2.30 reads: "Types of Troubleshooting Actions Recommended - Primary Treatment * Process and operational changes * Equipment repair * Cleaning and maintenance * Chemical additions"
B. Use Slide 179.2/4.2.31 to summarize purposes of troubleshooting.	Use Slide 179.2/4.2.31 Slide 179.2/4.2.31 reads: "Troubleshooting Actions Should * Solve immediate breakdown * Prevent recurrence * Improve long run maintenance and prevention of problems * Improve long run efficiency"
C. Use Slide 179.2/4.2.32 to summarize criteria for a successful troubleshooting project.	Use Slide 179.2/4.2.32 Slide 179.2/4.2.32 reads "Troubleshooter's Actions Must * Receive acceptance of operator * Be within financial and man-power capability * Keep plant within design criteria * Solve both short- and long-run problems"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
D. Use Slide 179.2/4.2.33 to stress importance of follow-up and documentation to successful troubleshooting.	Use Slide 179.2/4.2.33 Slide 179.2/4.2.33 reads: "Final Troubleshooting Steps Include * Overseeing implementation * Monitoring results * Documenting results * Follow-up"
E. In any remaining time, instructor should summarize the lesson and call for class questions and discussion.	Use Slide 179.2/4.2.34 Slide 179.2/4.2.34 is a blank slide used to blacken the screen.
F. Direct class to next activity on agenda.	

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 4: Pre/Primary Treatment

Lesson 2: Primary Treatment

Trainee Notebook Contents

Information Regarding Normal Operations of Primary Clarification T4.2.1

References T4.2.3

Information Regarding Normal Operations of Primary Clarification

Table 1 - Raw Sludge Characteristics

1. Physical Texture
    a. Non-uniform
    b. Lumpy
2. Color
    a. Fresh sludge - brownish in color
    b. Septic sludge - dark grey or black
3. Density
    a. Average solids content of 3 - 8%
4. Odor
    a. Normal domestic sludge will have a slight tarry odor
    b. Septic sludge will have an offensive odor
5. Volatile Matter
    a. Average range 70 - 80% of total dry solids
6. pH
    a. Average - 6.0
    b. Range - 5.5 - 6.5
7. Total Alkalinity
    a. Average 650 mg/l
    b. Range 300- 1,000 mg/l
8. Sludge Volume
    a. Average 250 - 350 ft^3/MG
    b. Range 70 - 700 ft^3/MG

T4.2.1

9. Grease Content
    a. Average 15 - 20 mg/l
10. Drainability on Sand Beds
    a. Poor
11. Digestibility
    a. Normally good

Relationship of Primary Treatment to Other Processes

1. Will remove 35 - 40% BOD load
2. Will remove 50 -70% suspended solids
3. Will remove 80 - 99% settleable solids
4. Will remove 90 - 94% grease
5. Will buffer shock load
6. Will increase efficiency of secondary treatment processes

REFERENCES

1. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA/430/9-78-001, Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (1978).
2. *Inspector Guide for Evaluation of Municipal Wastewater Treatment Plants*, EPA/430/9-79-010, Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (1979).
3. *Process Design Manual for Upgrading Existing Wastewater Treatment Plants*, Environmental Protection Agency, Technology Transfer, Cincinnati, OH (1974).
4. *Manual of Instruction for Sewage Treatment Plant Operators*, New York State Department of Health, Albany, NY.
5. *Operation of Wastewater Treatment Plants, A Home Study Course*, University of California at Sacramento, Sacramento, CA (1970).
6. *Operation of Wastewater Treatment Plants*, MOP 11, Water Pollution Control Federation, Washington, D.C. (1976).
7. *Manual of Wastewater Operations*, Texas Water Utilities Association, Austin, TX (1971).

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 5: Fixed Media Biological Systems

Unit 5 of 15 Units of Instruction

Lessons in Unit: 2 Recommended Time: 2 1/4 hours

Instructor Overview of the Unit

Rationale for Unit: The fixed media biological systems, trickling filter, activated biofilters and rotating biological contactors, are used widely in wastewater treatment as the secondary treatment process, as a roughing unit preceding secondary treatment or as a tertiary process for biological nitrification. Therefore, it is important that the troubleshooter understand mixed media biological systems and be able to recognize and solve problems in mixed media systems. This unit describes the operation of fixed media systems, identifies common problems in the operation of these systems and applies the process of troubleshooting to trickling filter case history problems.

Trainee Entry Level Behavior: The trainee should have completed Unit of Instruction 1: *Overview* and Unit of Instruction 2: *Elements of Troubleshooting* before beginning this Unit of Instruction. Completion of Units of Instruction 3 and 4 is suggested, but is not a mandatory prerequisite for this Unit.

Training Learning Objectives: At the conclusion of this unit of instruction, the trainee will be able to:

1. Using references, list and describe the factors affecting the performance of fixed media biological systems: trickling filters (TF), activated biofilters (ABF) and rotating biological contactors (RBC).
2. Using references, describe and compare the expected performance of TFs, ABFs and RBCs.
3. From memory, identify the steps in the Process of Troubleshooting and describe their application to problem solution for TFs, ABFs and RBCs.
4. From memory, recognize and employ the important human characteristics of troubleshooting behavior.

5. From memory, list observations to be made while troubleshooting TFs, ABFs and RBCs.

6. Using references, identify common deficiencies that can be observed in TFs, ABFs and RBCs.

7. From memory, list records to be kept at fixed media biological treatment plants and recognize the value of different types of plant records.

8. From memory, list process control tests to be run on TFs, ABFs and RBCs and explain their interpretation in operations and troubleshooting.

9. Using references, list and explain tests to be performed while troubleshooting TFs, ABFs and RBCs.

10. Using references, list and identify common operating problems with TFs, ABFs and RBCs.

11. Using references, apply the Process of Troubleshooting to identify the causes of common operating problems in TFs, ABFs and RBCs.

12. From memory, recognize and describe common problems in small, poorly staffed plants.

13. Using references, describe methods for upgrading TFs, ABFs and RBCs.

14. Demonstrate an ability to apply a systematic approach to problem solving in fixed media biological systems by using the Process of Troubleshooting to analyze and solve four fixed media biological systems problems.

    a. Identify the problem.
    b. List the likely causes of the problem.
    c. List the expected effects and symptoms of the problem identified.
    d. Obtain additional data needed to identify the probable cause of the problem.
    e. Recommend corrective measures for each probable cause.

15. Orally report and discuss the findings of the problem solving exercise.

Sequencing and Pre-Course Preparation for the Unit: The unit on fixed media biological systems is presented in two lessons.

Lesson 1: Troubleshooting Fixed Media Biological Systems

Recommended Time: 40 minutes

Purpose: Basic operational concepts for fixed media biological systems, trickling filters, activated biofilters and rotating biological contactors, are presented and discussed. The application of the Process of Troubleshooting to problem identification and solution in fixed media systems is presented.

Training Facilities:

1. Large room, preferably 40' by 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees.

2. Instructor table with lectern.

3. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.

4. Easel with pad.

5. 35mm carousel projector with remote control changer at instructor table.

6. At least four empty carousel trays.

7. Overhead projector.

8. Chalk, felt-tip markers, erasers, etc.

9. Six to eight chairs randomly spaced at back and sides of room for visitors.

Pre-Course Preparation:

1. Trainee Texts

   a. Order and have available at each trainee seating position *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA 430/9-78-001, Municipal Operations Branch, U. S. Environmental Protection Agency, Washington, D.C. (January, 1978).

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   1. *Trainee Notebook*, page T5.1.1, "Sampling and Testing Program for Trickling Filter Process."

3. Trainee Handout materials

   Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plans.

   a. None required for Lesson 1.

Instructional Approach: Illustrated lecture with class discussion.

Lesson 2: Applying the Process of Troubleshooting

Recommended Time: 90 minutes

Purpose: This lesson reinforces the Process of Troubleshooting by having the class solve a series of four realistic problems related to fixed media biological systems operation and maintenance.

Training Facilities: As specified for Lesson 1.

Pre-Course Preparation:

1. Trainee Texts

   a. As specified for Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   1. *Trainee Notebook*, pages T5.2.1 - T5.2.3, "Problem Answer Sheets, Problems 1 - 3."

   2. *Trainee Notebook*, pages T5.2.4 - T5.2.7, "Problem Statement and Answer Sheet for Problem 4."

   3. *Trainee Notebook*, page T5.4.8, "References."

3. Trainee Handout materials

Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plan.

a. None required for Lesson 2.

Instructional Approach: Trainee problem solving in groups of four with the trainees role playing troubleshooters and the instructor role playing the operator.

Presentation Options for the Course Director: The two and one quarter (2¼) hour unit on Fixed Media Biological Systems is an important part of the overall course material on troubleshooting. Two and one quarter hours are felt to be appropriate in relation to a total course effort of between 28 and 40 hours. It would be difficult to reduce this lesson below 2 hours and still maintain its continuity. Likewise, it is now recommended that the lesson be expanded, unless there is a particular need to emphasize fixed media systems. Therefore, any options for modifying the unit should be carefully considered by the Course Director. Subjects covered which could be expanded include:

Lesson 1 - Troubleshooting Fixed Media Biological Systems: Where additional detail is desired, this subdivision could be lengthened to 60 or 90 minutes. If it is extended beyond 60 minutes, it is suggested that slides showing trickling filter problems be obtained and used. Also, detailed diagrams of trickling filter construction and operation should be used if the students do not have a basic familiarity with trickling filters.

Lesson 2 - Applying the Process of Troubleshooting: This lesson could be extended to two hours or more by allowing 5 or more additional minutes to each problem presented to the class and additional time for discussion of the findings.

Summary of Unit of Instruction 5: Fixed Media Biological Systems

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Troubleshooting Fixed Media Biological Systems	1. Describe fixed media system factors and performance	1. Basic properties and expected performance of fixed media systems	1. Follow lesson outline	1. Slides 179.2/5.1.1-179.2/5.1.31
40 minutes	2. Identify appropriate steps in the Process of Troubleshooting	2. Importance of troubleshooter behavior	2. Rely upon slide series and lesson plans	2. Process of Troubleshooting Chart, *Trainee Notebook*, page T2.2.8
	3. Identify things to observe, records to review and process control tests for troubleshooting	3. Importance of daily log, observations and records		3. *Instructor Notebook*, pages 5.1.1 - 5.1.16
	4. List common operating problems and their causes	4. Importance of testing		4. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*
	5. Recognize problems in small plants	5. Special problems in dealing with small plants		5. *Trainee Notebook*, page T5.1.1

Summary of Unit of Instruction 5: Fixed Media Biological Systems (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
2. Applying the Process of Troubleshooting 90 minutes	1. Follow systematic approach to solving trickling filter problems	1. Four operational problems for student groups to identify and develop solutions	1. Trainees work in groups	1. Answer sheets, *Trainee Notebook*, pages T5.2.1 - T5.2.7
	2. Identify problems and their causes	2. Approach to ventilating trickling filters	2. Instructor presents problems with a brief description and slides	2. Slides 179.2/5.2.1 - 179.2/5.2.10
	3. List effects and symptoms of trickling filter problems	3. Troubleshooting small plants with part-time operators	3. Groups, through discussion, have 10 minutes to solve each problem as to identify, cause, effects, proposed correction	3. *Instructor Notebook*, pages 5.2.1 - 5.2.8
	4. Determine methods of correction for operating problems	4. Maintaining good distribution over filters	4. Group leaders present approaches to problems	4. Answer sheets, *Trainee Notebook*, pages T5.2.1-T5.2.7
	5. Compare approaches to solving trickling filter problems	5. Correcting ponding problems	5. Repeat slide depicting problems	5. Slides 179.2/5.2.11 - 179.2/5.2.19
	6. Evaluate problem approachs to the instructor's suggested solutions		6. Instructor stimulates discussion on groups' approaches	6. *Instructor Notebook*, pages 5.2.9 - 5.2.14
	7. Consider the merits of alternative approaches to trickling filter problems			7. *Trainee Notebook*, page T5.2.8, "References"

TROUBLESHOOTING O & M PROBLEMS IN
WASTEWATER TREATMENT FACILITIES

Unit of Instruction 5: Fixed Media Biological Systems

Lesson 1: Troubleshooting Fixed Media Biological Systems

Lesson 1 of 2 lessons Recommended Time: 40 minutes

Purpose: Basic operational concepts for fixed media biological systems, trickling filters, activated bio-filters and rotating biological contactors are presented and discussed. The application of the Process of Troubleshooting to problem identification and solution in fixed media systems is presented.

Trainee Entry Level Behavior: Trainees should have achieved the learning objectives specified for Unit of Instruction 2, *Elements of Troubleshooting*, before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson the trainee will be able to:

1. Using references, list and describe the factors affecting the performance of fixed media biological systems: trickling filters (TF), activated biofilters (ABF), and rotating biological contactors (RBC).
2. Using references, describe and compare the expected performance of TFs, ABFs and RBCs.
3. From memory, identify the steps in the Process of Troubleshooting and describe their application to problem solution for TFs, ABFs and RBCs.
4. From memory, recognize and employ the important human characteristics of troubleshooting behavior.
5. From memory, list observations to be made while troubleshooting TFs, ABFs and RBCs.
6. Using references, identify common deficiencies that can be observed in TFs, ABFs and RBCs.
7. From memory, list records to be kept at fixed media biological treatment plants and recognize the value of different types of plant records.

8. From memory, list process control tests to be run on TFs, ABFs and RBCs and explain their interpretation in operations and troubleshooting.

9. Using references, list and explain tests to be performed while troubleshooting TFs, ABFs and RBCs.

10. Using references, list and identify common operating problems with TFs, ABFs and RBCs.

11. Using references, apply the Process of Troubleshooting to identify the causes of common operating problems in TFs, ABFs and RBCs.

12. From memory, recognize and describe common problems in small, poorly staffed plants.

13. Using references, describe methods for upgrading TFs, ABFs and RBCs.

Instructional Approach: Illustrated lecture with class discussion.

Lesson Schedule: The 40 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 15 minutes	Characteristics of Fixed Media Systems
15 - 25 minutes	Troubleshooting Fixed Media Systems
25 - 40 minutes	Operational Problems in Fixed Media Systems

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, page T5.1.1, "Sampling and Testing Program for Trickling Filter Process."

2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*

    a. Trickling Filters, pages 77-95
    b. Rotating Biological Contactors, pages 110-117
    c. Activated Biofilters, pages 96-99

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 5.1.1 - 5.1.16, Unit 5, Lesson 1.

2. Slides 179.2/5.1.1 - 179.2/5.1.31.

Instructor Materials Recommended for Development: None

Additional Instructor References:

1. *Operations Manual, Aerobic Biological Treatment Systems*, EPA 430/9-77-006, Municipal Operations Branch, U. S. Environmental Protection Agency, Washington, D.C. (March, 1977).
2. *Operation of Wastewater Treatment Plants, MOP 11*, Water Pollution Control Federation, Washington, D.C. (1976).
3. *Instructor Notebook*, Unit of Instruction 2: Elements of Troubleshooting.

Classroom Set-Up:

1. Large room, preferably 40' by 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees.
2. Instructor table with lectern.
3. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.
4. Easel with pad.
5. 35mm carousel projector with remote control changer at instructor table.
6. At least four empty carousel trays.
7. Overhead projector.
8. Chalk, felt-tip marker, erasers, etc.
9. Six to eight chairs randomly spaced at back and sides of room for visitors.

LESSON OUTLINE

I. Characteristics of Fixed Media Biological Systems (15 minutes)

   A. Types of Fixed Media Systems

      1. Define fixed media system by contrasting to activated sludge, a suspended media system.

         a. Microorganisms which stabilize the waste are fixed as growth or slime to the media.

         b. The wastewater (food) then flows over the media or the media is moved through the wastewater.

         c. Fixed media advantages include:

            1) Relatively simple operation.

            2) Lower cost operation.

            3) Stable systems compared to suspended media system.

            4) Growth and retention of slower growing organisms, such as nitrifiers, is encouraged because of long effective "MCRT" in fixed media systems.

            5) Lower sludge production than suspended media systems.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/5.1.1
Slide 179.2/5.1.1 is a blank

Key Point: Course is designed for operation specialists. Therefore, the assumption should be made that the students are generally familiar with components and characteristics of fixed media biological systems and the introductory information can be covered as quickly as possible.

Use Slide 179.2/5.1.2
Slide 179.2/5.1.2 is a word slide which reads:

"Types of Fixed Media Systems

1. Trickling Filters (TF)
2. Activated Bio-Filter (ABF)
3. Rotating Biological Contactor (RBC)"

Refer class to *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*:

a. Trickling Filter, pp. 77-95
b. Activated Bio-Filter, pp. 96-99
c. Rotating Biological Contactor, pp. 110-117.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Discuss following briefly as examples of fixed media biological systems: a. Trickling Filter (TF) b. Activated Bio-Filter (ABF) c. Rotating Biological Contactors (RBC)	
B. Trickling Filters 1. Using Slide 179.2/5.1.3, identify trickling filter components	Use Slide 179.2/5.1.3 Slide 179.2/5.1.3 is a schematic diagram of cut-away of a circular trickling filter.
a. Distribution system b. Filter media 1) Rock 2) Redwood slats, page 82, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities.* 3) Plastic, page 83, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities.* c. Underdrain system d. Discuss media characteristics	
2. Use Slide 179.2/5.1.4 to illustrate trickling filter rotary arm distribution of wastewater and relate components to schematic.	Use Slide 179.2/5.1.4 Slide 179.2/5.1.4 is a photograph showing the surface of the media and the distribution arm of a circular trickling filter.
3. Use Slide 179.2/5.1.5 to illustrate fixed nozzle distribution system.	Use Slide 179.2/5.1.5 Slide 179.2/5.1.5 is a photograph showing a fixed nozzle trickling filter. The nozzles are distributing wastewater.

LESSON OUTLINE

4. Dosing fixed nozzle trickling filter.

   a. Refer class to page 79, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* for schematic of fixed nozzle trickling filter and dosing siphon.

   b. Use Slides 179.2/5.1.6 and 179.2/5.1.7 to illustrate dosing cycle for fixed nozzle system.

   c. Note to class that rotary distribution system is more commonly encountered in the field.

C. Activated Bio-Filter Process (ABF)

1. Combination of activated sludge and trickling filter.

2. Refer class to page 97, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* for schematic of ABF system (same as Slide 179.2/5.1.8).

3. Identify and explain purpose of ABF system components:

   a. ABF tower

   b. ABF tower media is usually redwood slats

   c. Aeration tank

   d. Clarifier

   e. Return sludge

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/5.1.6

Slide 179.2/5.1.6 is a photograph of a trickling filter media bed with fixed nozzle distribution. The nozzles are not functioning.

Use Slide 179.2/5.1.7

Slide 179.2/5.1.7 is a photograph of a fixed nozzle trickling filter after the dosing siphon has loaded the filter.

Use Slide 179.2/5.1.8

Slide 179.2/5.1.8 is a schematic diagram of an ABF system. Slide is identical to the figure on page 97 of the *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
4. Note that ABF system potentially has operational problems of both trickling filter and activated sludge systems.	
D. Rotating Biological Contactor (RBC)	Refer class to page 111, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* for schematic of RBC system.
1. Describe operation of RBC unit Disc turns, carrying film of wastewater into exposure with air, oxygenated in this manner. Shear forces of rotation cause slough off to form mixed liquor. Rotation agitation keeps solids in suspension.	
2. Identify RBC components a. Media disc assembly b. Drive assembly c. Wastewater tank d. Cover	Use Slide 179.2/5.1.9 Slide 179.2/5.1.9 is a photograph of an end view of a rotating biological contactor unit. The photo shows the cover housing, the media disc, the shaft, the liquid holding tank and the drive motor assembly.
3. RBC performance characteristics a. Approximately 40% of each disc submerged b. Concentration of biomass - 50,000 to 100,000 mg/l. Equivalent to 10,000-20,000 mg/l MLSS suspended system. c. Growth very filamentous, provides great surface area.	
4. Note that RBC units are normally fully enclosed.	Use Slide 179.2/5.1.10 Slide 179.2/5.1.10 is a photograph of a RBC system totally enclosed in its cylindrical covers.

LESSON OUTLINE

E. Fixed Media Systems can be expected to achieve:

  1. 80-85% BOD removal

  2. 80-85% Suspended solids removal

F. Factors Affecting Fixed Media System Performance

  1. Use Slide 179.2/5.1.11 to list factors affecting fixed media system performance.

  2. Encourage class discussion of the significance of each factor.

  3. Discuss each point briefly.

    a. Loadings must be proper to achieve desired removals.

    b. Temperature affects efficiency of microorganisms.

    c. Too high BOD - ponding caused by extensive growth
    Toxic wastes - no growth

    d. Balance load distribution to prevent ponding.

    e. Ventilation provides oxygen for aerobic organisms.

    f. Media voids provide ventilation, surface area, active sites.

    g. Underdrains provide for even load distribution and ventilation. Balance flow patterns distribute food evenly in RBC.

KEY POINTS & INSTRUCTOR GUIDE

Cite design and performance tables in *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*

TF - page 84 Review these to the
ABF - page 98 extent class interest
RBC - page 110 indicates

Use Slide 179.2/5.1.11
Slide 179.2/5.1.11 is a word slide which reads:

"Factors Affecting Fixed Media System Performance

1. Proper Design
2. Climate
3. Character of Wastes
4. Distribution of Wastewater Over Media
5. Ventilation
6. Condition of Media
7. Proper Underdrain System or Flow Pattern"

LESSON OUTLINE

II. Troubleshooting Fixed Media System Operations (10 minutes)

A. Elements of Troubleshooting

1. Refer class to *Trainee Notebook*, page T2.2.8, "The Process of Troubleshooting."
2. Using Slide 179.2/5.1.12, review the steps in the process of troubleshooting:
    a. Identify problems through observation.

    b. Analyze conditions and determine causes of problems.

    c. Determine solutions to problems.

    d. Select and implement best solution.

B. Beginning the Process of Troubleshooting

1. Use Slide 179.2/5.1.13 to review initial steps in the Process of Troubleshooting.

KEY POINTS & INSTRUCTOR GUIDE

Key Point: The emphasis on this section of the lesson is to review and reinforce the steps in the *Process of Troubleshooting* by applying the process to problem identification and solution in trickling filter plants. A secondary thrust is to direct attention to problems faced by the operator of small treatment plants which may be staffed with less than one man year available for treatment plant operations.

The instructor should review *Unit of Instruction 2: Elements of Troubleshooting* before beginning this lesson.

Use Slide 179.2/5.1.12
Slide 179.2/5.1.12 is a word slide which reads:

"Basic Elements of Troubleshooting

Review of Plant Conditions
Communication and Observation
Analysis and Testing
Formulation of Alternative Actions
Corrective Actions - Trial and Error
Long Range Implementation
Monitor, Document and Follow-Up"

Use Slide 179.2/5.1.13
Slide 179.2/5.1.13 is a word slide which reads:

"Beginning the Process of Troubleshooting

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
	Visit Plant, Meet and Listen Observe Review Records Sample, Test and Analyze"
2. Use Slide 179.2/5.1.14 to stress the key elements of troubleshooter behavior.	Use Slide 179.2/5.1.14 Slide 179.2/5.1.14 is a word slide which reads: "Important Elements of Troubleshooting Personal Contact with Operator and Staff Tour Plant with Operator Concern for Operators Problems Understanding His/Her Difficulties Obtaining the Operator's Point of View and Opinion Listening"
3. Use Slide 179.2/5.1.15 and have class recommend observations applicable to trickling filters. Encourage discussion!	Use Slide 179.2/5.1.15 Slide 179.2/5.1.15 is a word slide which reads: "Observations - Things to Look For While Troubleshooting Trickling Filters"
4. Use Slide 179.2/5.1.16 to summarize some of key observations. Supplement slide with any other observations surfaced by the class. a. Condition of plant grounds b. Color and condition of media c. Distribution of wastewater over media d. Condition of receiving stream e. Maintenance and physical condition of filters f. Use of safety precautions	Use Slide 179.2/5.1.16 Slide 179.2/5.1.16 is a word slide which reads: "Observations - Trickling Filter Condition of Plant Grounds Color of Media - Dark Green? Do Arms Move at Uniform Rate" Condition of Receiving Stream Maintenance and Physical Condition of Filter Use of Safety Precautions"

LESSON OUTLINE

5. Use Slide 179.2/5.1.17 to list some common deficiencies to observe with fixed media systems.

    a. Solids and grease in effluent

    b. Seal leakage (TF)

    c. Clogged nozzles (TF)

    d. Splash plate adjustment (TF)

    e. Drive chain or belt problem (RBC)

    f. Others - lead discussion with class to identify other common fixed media system problems

6. Use Slide 179.2/5.1.18 to review fixed media records which should be maintained.

    a. Flow records

    b. Daily log, problems and maintenance

    c. Lab test results:

        1) Process control

        2) Effluent (NPDES)

    d: Pretreatment and industrial controls

    e. Use next five slides to discuss importance of records. Use this as an opportunity to compare and contrast large vs. small plant problems.

        1) Importance of flow records. Use Slide 179.2/5.1.19.

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/5.1.17

Slide 179.2/5.1.17 is a word slide which reads:

"Trickling Filters - Common Deficiencies to Observe

Solids and Grease in Effluent
Seal Leakage
Clogged Nozzles
Splash Plate Adjustments"

Use Slide 179.2/5.1.18

Slide 179.2/5.1.18 is a word slide which reads:

"Records to Review

Flow Records
Daily Log, Problems and Maintenance
Test Results - Process Controls
Test Results - Effluent
Pretreatment and Industrial Controls"

Use Slide 179.2/5.1.19

Slide 179.2/5.1.19 is a word slide which reads:

"Importance of Flow Records

Are Filters Being Loaded Equally?
Do Flow Meters Function Properly?
When Were Meters Calibrated?
Can Improvements Be Suggested?"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
2) Use the daily log. Use Slide 179.2/5.1.20 to discuss importance of the daily log.	Use Slide 179.2/5.1.20 Slide 179.2/5.1.20 is a word slide which reads: "Use the Daily Log! Are Maintenance Activities Recorded? Do They Yield Useful Information? What Problems Have Occurred? Has Weather Been a Factor? Is Information in Log Honest?"
3) Lab testing - process control Use Slide 179.2/5.1.21 to review troubleshooting issues related to lab testing for process control uses.	Use Slide 179.2/5.1.21 Slide 179.2/5.1.21 is a word slide which reads: "Process Control Testing Results Review Lab Methods Are the Most Useful Tests Being Run? Are They Fudging the Results? Develop Honest Communication with the Operator"
4) Lab testing - effluent monitoring Use Slide 179.2/5.1.22 to review troubleshooting issues related to testing for effluent monitoring.	Use Slide 179.2/5.1.22 Slide 179.2/5.1.22 is a word slide which reads: "Effluent Test Results Are NPDES Requirements Being Met? If Not, Why? Can the Plant, If Well Operated, Meet the Requirements? Do They Know Why the Plant is Performing Poorly?"
5) Use Slide 179.2/5.1.23 to review troubleshooting issues related to pretreatment and industrial control.	Use Slide 179.2/5.1.23 Slide 179.2/5.1.23 is a word slide which reads: "Pretreatment and Industrial Controls

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDES

Do They Exist?
Do They Effectively Enhance the Trickling Filter Operation?
Review with the Operator - An Alert Troubleshooter Can Assist"

7. Sampling and Testing for Fixed Media Biological Systems

   a. Refer class to page T5.1.1 in the *Trainee Notebook* for a recommended trickling filter sampling and testing program.

   b. Use Slide 179.2/5.1.24 to highlight key testing requirements.

Use Slide 179.2/5.1.24
Slide 179.2/5.1.24 is a word slide which reads:

"Sample and Test

Minimum Requirements for Process Control:

1. BOD - Daily
2. Suspended Solids - Daily

Optional: COD"

   c. Use Slide 179.2/5.1.25 to discuss additional test, observations or records useful to the troubleshooter and operator.

Use Slide 179.2/5.1.25
Slide 179.2/5.1.25 is a word slide which reads:

"Useful Testing for Troubleshooting Trickling Filters

Temperature (Icing Problems)
Flow and Recirculation Rates
Sulfides (Odor Problems)
Size and Uniformity of Media
Growths, Larvae and Snails
Organic Load on Filter"

III. Operational Problems - Fixed Media Systems (15 minutes)

   A. Trickling Filters

LESSON OUTLINE

1. Refer class to troubleshooting guides on pages 92-95, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*.

2. Review common trickling filter problems.

   a. Have class identify probable causes for each problem and discuss possible corrective actions.

      1) Ponding - overloaded filters and clogged media.

      2) Odors - organic overload and anaerobic conditions upstream

      3) Filter flies - often found in low rate filters. Caused by alternating wet and dry environment.

      4) Icing - uneven distribution during freezing weather.

      5) Uneven distribution - malfunction in waste distribution system, including nozzle clogging, seal leaks or poor spray pattern.

      6) Industrial shock loads - no pretreatment ordinance, no flow equalization or pretreatment capability in plant.

      7) Heavy sloughing - changes in loadings or operations.

B. Rotating Biological Contactors

1. Refer class to troubleshooting guides on pages 116-117, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*.

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/5.1.26

Slide 179.2/5.1.26 is a word slide which reads:

"Common Trickling Filter Problems

Ponding
Odors
Filter Flies
Icing
Uneven distribution
Industrial Shockloads
Heavy Sloughing of Growth"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
2. Review common RBC problems	
a. Use Slide 179.2/5.1.27 to list common problems in RBC systems. Have class identify causes and corrective actions.	Use Slide 179.2/5.1.27 Slide 179.2/5.1.27 is a word slide which reads:
1) Heavy sloughing - toxic materials or excessive pH variation.	"Common RBC Problems Heavy Sloughing of Growth Decreased Treatment Efficiency Biomass Turns White Solids Accumulation in Reactors Bearings and Motor Overheating and Failure"
2) Decreased treatment efficiency - organic or hydraulic overload, pH too high or too low, low temperatures.	
3) Biomass turns white - septic influent, first stage organic overloaded.	
4) Solids accumulation - inadequate pretreatment.	
5) Bearings and motor overheat - inadequate maintenance, improper drive chain alignment, excessive solids on discs.	
C. Activated Biofilter Systems	Use Slide 179.2/5.1.28 Slide 179.2/5.1.28 is a blank.
1. Refer class to pages 96-99, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*.	
2. ABF problems are similar to those of:	
a. Trickling filter	
b. Activated sludge	
3. Causes and corrective actions are covered for:	
a. Trickling filter	
b. Activated sludge	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
D. Small Plant Operator Problems 1. One additional problem should be noted, poor operations due to part-time supervision in small plants.	Use next two slides to highlight problems which are encountered in the small plant. Encourage class discussion of significance of these small plant constraints and discussion of what the troubleshooter can do to help small plants
2. Discuss points on Slide 179.2/5.1.29 which describes small plant problems.	Use Slide 179.2/5.1.29 Slide 179.2/5.1.29 is a word slide which reads: "Small Plant Problems Part Time, Busy Operators Low Priority of Operations Fiscal Constraints Physical Constraints of Plant Fluctuating Loads Seldom Have Adequate Reporting"
3. Discuss points on Slide 179.2/5.1.30 which lists some possible troubleshooter roles when working with small plants.	Use Slide 179.2/5.1.30 Slide 179.2/5.1.30 is a word slide which reads: "How to Help Small Plants Encourage and Assist Operator Communicate with Operator on His/Her Level Help Operator Get $ from Community Seek Plant Flexibility if Possible Simplify Reporting" Use Slide 179.2/5.1.31 Slide 179.2/5.1.31 is a blank.

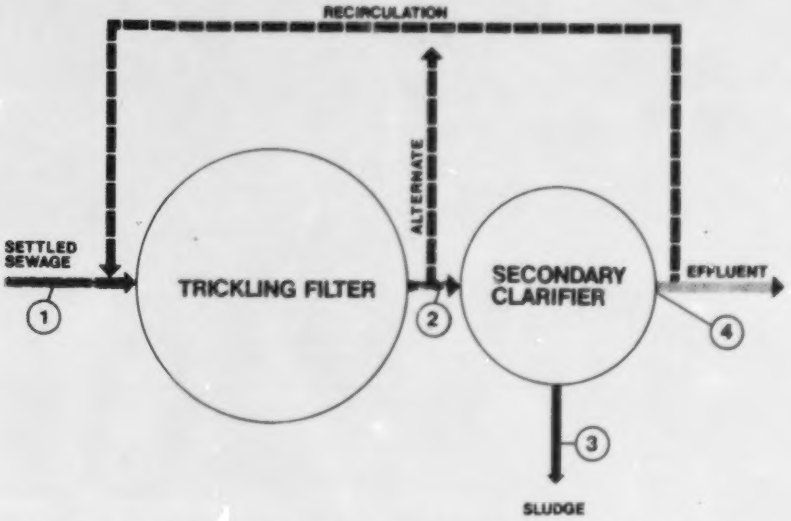
TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 5: Fixed Media Biological Systems

Lesson 1: Troubleshooting Fixed Media Biological Systems

Trainee Notebook Contents

Sampling and Testing Program for
Trickling Filter Process T5.1.1



SAMPLE LOCATIONS FOR TYPICAL TRICKLING FILTER PROCESS

DESCRIPTION	SETTLED SEWAGE (PRIMARY EFFLUENT)	FILTER EFFLUENT	SLUDGE (UNDER FLOW)	SECONDARY CLARIFIER EFFLUENT	FREQUENCY 1 TO 5 MGD	FREQUENCY 5 MGD AND LARGER	TYPE OF SAMPLE	METHOD OF TEST	APPLICATION OF TEST
FLOW	CR	—	—	CR	—	—	—	—	P
BOD	☒			☒	1/W	2/W	C	AM	P
COD	☒			☒	1/W	2/W	C	AM	P
SUSPENDED SOLIDS TOTAL	☒	☒		☒	1/W	2/W	C	AM	P
SUSPENDED SOLIDS VOLATILE	☒			☒	1/W	2/W	C	AM	P
SETTLEABLE SOLIDS	☒	☒		☒	D	D	C	AM	P
AMMONIA ●	☒			☒	2/M	1/W	C	AM	P
NITRITE ●				☒	2/M	1/W	C	AM	P
NITRATE ●				☒	2/M	1/W	C	AM	P
PHOSPHORUS	☒			☒	2/M	1/W	C	AM	P
DO				☒	1/W	2/W	G	AM	P
pH	☒		☒	☒	D	D	G	AM	S
TEMPERATURE	☒			☒	D	D	G	AM	S
TOTAL & VOLATILE SOLIDS			☒		1/W	2/W	C	AM	P
LOCATION OF SAMPLE	①	②	③	④					

● NOT APPLICABLE TO SINGLE-STAGE HIGH-RATE AND ROUGHING-RATE FILTERS

CODE DESCRIPTION			
☐	SAMPLE	S	SURVEILLANCE
☒	TEST RESULTS CALCULATED	W	WEEK
②	DENOTES SAMPLE LOCATION	M	MONTH
C	COMPOSITE	AM	ANALYTICAL MEASUREMENT
D	DAILY	CR	CONTINUOUSLY RECORDED AND TOTALIZED
G	GRAB	MM	MAKE MEASUREMENT
P	PROCESS CONTROL	PM	PHYSICAL MEASUREMENT

SAMPLING AND TESTING PROGRAM FOR

TRICKLING FILTER PROCESS

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 5: Fixed Media Biological Systems

Lesson 2: Applying the Process of Troubleshooting

Lesson 2 of 2 lessons Recommended Time: 90 minutes

Purpose: This lesson reinforces the *Process of Troubleshooting* by having the class solve a series of four realistic problems related to fixed media biological systems operation and maintenance.

Trainee Entry Level Behavior: Trainees shall have completed Unit of Instruction 5, Lesson 1, before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. Demonstrate an ability to apply a systematic approach to problem solving in fixed media biological systems by using the Process of Troubleshooting to analyze and solve four fixed media biological systems problems.
    a. Identify the problem.
    b. List the likely causes of the problem.
    c. List the expected effects and symptoms of the problem identified.
    d. Obtain additional data needed to identify the probable cause of the problem.
    e. Recommend corrective measures for each probable cause.
2. Orally report and discuss the findings of the problem solving exercise.

Instructional Approach: Trainee problem solving in groups of four with the trainees role playing troubleshooters and the instructor role playing the operator.

Lesson Schedule: The 90 minutes allocated to this lesson should be allocated as follows:

TIME	SUBJECT
0 - 5 minutes	Introduce Problem Session in Class
5 - 15 minutes	Problem 1
15 - 25 minutes	Problem 2
25 - 35 mintues	Problem 3
35 - 45 minutes	Problem 4
45 - 55 minutes	Reporting and Analysis of Problem 1
55 - 65 minutes	Reporting and Analysis of Problem 2
65 - 75 minutes	Reporting and Analysis of Problem 3
75 - 85 minutes	Reporting and Analysis of Problem 4
85 - 90 minutes	Lesson Summary and Conclusions

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T5.2.1 - T5.2.3, "Problem Answer Sheets, Problems 1 - 3."
2. *Trainee Notebook*, pages T5.2.4 - T5.2.7, "Problem Statement and Answer Sheet for Problem 4."
3. *Trainee Notebook*, page T2.2.8, "The Process of Troubleshooting."
4. *Trainee Notebook*, page T5.2.8, "References."

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 5.2.1 - 5.2.14, Unit 5, Lesson 2.
2. Slides 179.2/5.2.1 - 179.2/5.2.19.

Instructional Materials Recommended for Development: None

Additional Instructor References: None

Classroom Set-Up: As specified for Unit 5, Lesson 1.

Instructor Introduction to Problem Presentation Portion of the Lesson

A. Instructor role plays the operator; trainees role play troubleshooters.

B. The trainees should be seated in 4-person work groups previously selected by Course Director.

C. Each group should have answer sheets for the fixed media problems. Answer sheets are found on pages T5.2.1 -T5.2.7 in the *Trainee Notebook*.

D. Each group should designate one person as discussion leader for Problem 1, a second person for Problem 2, etc.

E. Each problem presentation and solution is allotted approximately 10 minutes as follows:

2 minutes - presentation by instructor using slides
8 minutes - analysis by trainee groups

F. For each problem, the instructor is to show designated slides, according to the lesson plan outline, from which the trainees are to identify the problem. In addition, some supplementary information is provided to the instructor. The instructor will give this information in response to trainee group questions but will not volunteer the information.

G. During the analysis period, the instructor may choose to answer questions or may decline. If a question is answered for one group, the same information is to be provided to all groups.

H. The instructor should encourage trainee participation and discussion within each group.

I. Each group, led by the discussion leader, is to jointly analyze the problems and provide the following on the answer sheet:

- a. Statement of the problem;
- b. Likely cause;
- c. Expected effects and symptoms;
- d. Proposed methods of correction.

J. The instructor must advise the class that they have 10 minutes for each problem and accordingly move on to the next problem.

K. Following this portion of the lesson, there will be another 45 minute session to discuss and analyze the problems in group discussion.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
I. Introduction to Problem Analysis (5 minutes)	Use Slide 179.2/5.2.1 Slide 179.2/5.2.1 is a blank.
A. Make sure trainees are seated with their groups and have answer sheets available to them. (*Trainee Notebook* pages T5.2.1 - T5.2.7)	Guide: Groups are to be predesinated by the Course Director. Each group should be a balanced cross section of the course's students.
B. Briefly review the instructions for this subdivision.	Four problems will be presented and analyzed. Following presentation of problem 4, groups will report their findings and the class will discuss solutions offered to the problems.
C. Stress that you are looking for the trainees to use the elements of the Process of Troubleshooting in their systematic approach to solving the problems.	
D. Stress that trainee participation and involvement is sought.	
E. Inform the class that you will role play the operator and try to answer any questions.	
II. Problem 1 (10 minutes)	
A. Problem Statement - read to class	Guide: 2 minutes
"You are dispatched to a trickling filter plant where there has been complaints of odors (we have no sample odors here for you to observe).	
You inspect the incoming sewer system and the flows are not septic.	
The filter surface looks like this	Use Slide 179.2/5.2.2 Slide 179.2/5.2.2 is a photograph showing the wall and surface of the rock media in a trickling filter. The rock appear to be broken and varying in size with many small rocks.
while the filter media looks like this."	Use Slide 179.2/5.2.3 Slide 179.2/5.2.3 is a close-up view of the media in the trickling filter described in Slide 179.2/5.2.2.
	Keep this slide on. Reshow slides as requested by class.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
B. Problem Solving Exercise	Guide: 8 minutes
Instruct class to use their answer sheets and in group discussion identify:	
1. Likely cause	
2. Expected effects and symptoms	
3. Proposed methods of correction	
C. Additional information if asked by trainees:	
1. It is not summer and there has not been a spell of hot weather.	
2. Type of filter - high rate	
3. Capacity of plant - 0.8 MGD	
4. Inflow BOD - 200 mg/l	
5. Recirculation ratio - 1:1	
D. Remind the class there are 10 minutes for this problem.	
III. Problem 2 (10 minutes)	Use Slide 179.2/5.2.4 Slide 179.2/5.2.4 is a blank.
A. Problem Statement - read to class.	Guide: 2 minutes
"Permit monitoring reports submitted to your office for the Obetz city trickling filter plant show a recent loss in removal efficiency with significant increases in BOD and suspended solids in the final effluent.	
As you arrive at the plant, one of the trickling filters looks like this	Use Slide 179.2/5.2.5 Slide 179.2/5.2.5 is a photograph of a small rock-filled trickling filter with circular distribution arms. The photograph shows that several distribution nozzles are plugged and that liquid distribution over the media is uneven.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
while the other one looks like this."	Use Slide 179.2/5.2.6 Slide 179.2/5.2.6 is a photograph showing another view of the trickling filter shown in Slide 179.2/5.2.5 which highlights the uneven flow distribution over the media. Keep this slide on. Repeat as requested by class.
B. Problem Solving Exercise	Guide: 8 minutes
Instruct the class to use their answer sheets and in group discussion identify:	
1. Likely causes	
2. Expected effects and symptoms	
3. Proposed methods of correction	
C. Answers to questions if asked:	
1. Obetz has a population of 6,000 people, a small seasonal vegetable cannery and three chicken farms.	
2. There have been periodic breakdowns of the primary and pretreatment systems, resulting in poor grease removal and periodic instances of high influent solids.	
D. Remind the class there are 10 minutes for this problem.	
IV. Problem 3 (10 minutes)	Use Slide 179.2/5.2.7 Slide 179.5.2.7 is a blank
A. Problem Statement - read to class.	Guide: 2 minutes
"As you approach a trickling filter plant on a routine inspection you make a mental note that this should be an easy day because the plant is usually well run. As you inspect the filters you see this	Use Slide 179.2/5.2.8 Slide 179.2/5.2.8 is a photograph of a surface of a trickling filter experiencing ponding. Liquid is

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
	clearly visible on the surface of the rock media. In the upper lef hand corner of the photograph the distribution arm has just passed and the spray coming off the filt can be seen.
and in some spots, this."	Use Slide 179.2/5.2.9 Slide 179.2/5.2.9 is a close-up photograph of the rock surface of the ponding media shown in Slide 179.2/5.2.8. Keep this slide on. Repeat slide as requested by the class.
B. Problem Solving Exercise	Guide: 8 minutes
Instruct class to use their answer sheets and in group discussion identify:	
1. Likely causes	
2. Expected effects and symptoms	
3. Proposed methods of correction	
C. Answers to questions if asked:	
1. There has been no heavy rain lately.	
2. Each filter (there are two) has a surface area of 2,000 square feet.	
3. The plant is loaded at a rate of 2 MGD.	
D. Remind the class that they have 10 minutes for this problem	
V. Problem 4 (10 minutes)	Use Slide 179.2/5.2.10 Slide 179.2/5.2.10 is a blank.
A. Problem Statement	Guide: 2 minutes
1. Refer class to *Trainee Notebook*, pages T5.2.4 to T5.2.7 for problem statement and background information.	

LESSON OUTLINE

2. Review problem statement and information with class as necessary.

B. Instruct the class to use their answer sheets located on page T5.2.7 in the *Trainee Notebook* and in group discussion identify:

   1. Likely causes

   2. Expected effects and symptoms

   3. Proposed methods of correction

C. Remind the class that there are 10 minutes for this problem.

KEY POINTS & INSTRUCTOR GUIDES

Guide: 8 minutes

Instructor Introduction to Reporting and Discussion Portion of the Lesson:

A. Trainees should remain in the trainee groups.

B. Each group selected a discussion leader for each of the problems presented. The instructor should call on one discussion leader for each problem to report his/her group's findings. Have other discussion leaders for that problem make additions.

C. While discussing each problem, show the slides which accompanied the problem. These slides are duplicates of those used previously.

D. If a problem is not completely solved by the class, use materials provided in the lesson plan outline to supplement discussion.

   The instructor should serve as a discussion catalyst for this

VI. Troubleshooting Guide to Problem 1 (10 minutes)

A. Identity of Problem

As stated, this was an odor problem.

B. Likely Causes

1. Since the plant inflows are not septic, the most likely cause is inadequate ventilation within the filter.

    a. Air and water temperatures may be equal and no thermal exchange takes place.

    b. Media may be broken or too small and blinded.

2. During hot weather, odors may develop from a filter in good operating condition.

C. Effect and Symptoms of Problem

1. Black slimes are likely to develop on the media surface.

2. Hydrogen sulfide odors develop in the vicinity of the filters.

3. Nitrification is not occurring - no breakdown: NH_3^+ → Nitrite → Nitrate

lesson. He/she should minimize his/her own role and maximize trainee participation.

E. Allow 10 minutes per problem, then move on to the next problem.

F. After 40 minutes, sum up the lesson on fixed media biological systems.

Use Slides 179.2/5.2.11 and 179.2/5.2.12 to illustrate points in the discussion as appropriate. These slides are identical to slides 179.2/5.2.2 and 179.2/5.2.3, respectively.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
D. Proposed Methods of Correction	
1. Maintain aerobic conditions in and properly operate sewer system and settling tanks.	Guide: If necessary the instructor should challenge the students into stating how these measures can be implemented.
2. Examine underdrain system and ventilation facilities; stoppages in either of these will cut down natural flow of air; natural ventilation occurs if vents are open and difference in air and water temperature is greater than $3^{o}F$.	
3. Increase recirculation rate to provide oxygen and to increase sloughing of surface slime.	
4. Practice good housekeeping around filter; keep slime growths, resulting from wastewater splashing, off sidewalks and other surfaces.	
5. In extreme cases, it may be necessary to provide forced air ventilation.	
VII. Troubleshooting Guide to Problem 2 (10 minutes)	Use Slide 179.2/5.2.13 Slide 179.2/5.2.13 is a blank.
A. Identity of Problem The problem shown is one of poor and uneven distribution of waste over the filter, including clogged nozzles and leaking seals.	Use Slides 179.2/5.2.14 and 179.2/5.2.15 as appropriate in discussion of the problem. Slides are identical to Slides 179.2/5.2.5 and 179.2/5.2.6, respectively.
B. Likely Causes	
1. Poor spray pattern on filter	
2. Nozzle clogging	
3. Leakage of seals	
4. Continued or frequent clogging indicates solids carry-over from primaries; may be due to abnormal loadings to plant or grease or suspended solids. During fall of year, sewer clogging due to leaves is a possible cause.	

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDES

C. Effects and Symptoms of Problem

1. Less efficient waste removal by filter due to uneven loading.

2. Sloughing of filter growths.

3. Ponding on certain areas of filter media and drying on others.

D. Proposed Methods of Correction

1. Adjust splash plates; clean slime growth off plates; replace missing plates.

2. Clean nozzles regularly with small wire or brush and thoroughly flush distributor piping.

3. Attempt to correct seal leakage problems, which are common. Some seal leakage may be normal.

VIII. Troubleshooting Guide to Problem 3 (10 minutes)

Use Slide 179.2/5.2.16
Slide 179.2/5.2.16 is a blank.

A. Identity of Problem

Use Slides 179.2/5.2.17 and 179.2/5.2.18 as appropriate to illustrate the discussion. Slides are identical to Slides 179.2/5.2.8 and 179.2/5.2.9, respectively.

The slides showed a case of severe filter ponding, which in this case was due to excessive loading without a corresponding high recirculation rate.

Filter Ponding - occurs when voids between filter media are clogged by biological slimes or inert materials. Ponding problems can sometimes be anticipated by periodically inspecting lower levels of rock.

B. Likely Causes

1. Excessive organic loading without corresponding high recirculation rate; organic load too heavy in comparison with hydraulic load.

2. Media too small or not sufficiently uniform in size.

LESSON OUTLINE

3. Media deterioration due to improper material selection or freezing.

4. Voids becoming clogged by excessive growth of insect larvae or snails (Perrywinkle snails quite common on filters).

C. Effect and Symptoms of Problem

1. Ponding on filter surface.

2. Intermittent flooding of filter.

D. Proposed Methods of Correction

(for intermittent ponding, caused primarily by excessive loading or by temporary clogging)

Ponding can be eliminated by several methods. In order of least effect on effluent, corrective measures include:

1. Jet surface with high pressure stream of water.

2. Stop distributor over ponded area; flush excessive growth from voids.

3. Stir or rake filter surface to lessen or remove any accumulations.

4. Dose filter with chlorine at about 5 mg/l for several hours; do during low flow periods to minimize required chlorine dosage (less preferable).

5. If possible, flood filter and allow it to stand for 24 hours; don't let water rise high enough to get into distributor bearings; resulting liquid is a mess to dump (less preferable).

6. If the problem is caused by snails, pesticides can be used (see note).

KEY POINTS & INSTRUCTOR GUIDES

Note: State regulations need to be observed any time pesticides are considered in a treatment plant.

E. Proposed Methods of Correction (for continual ponding)

For continual ponding, filter must be dismantled to determine what specific cause is, then take the necessary corrective action.

1. Media too small or non-uniform - screening and/or replacement is in order.
2. Media deterioration - media must be replaced.
3. Broken or clogged underdrains - flush out underdrain system or remove media and make necessary repairs. In most cases, media replacement will be necessary.

IX. Troubleshooting Guide to Problem 4 (10 minutes)

Use Slide 179.2/5.2.19
Slide 179.2/5.2.19 is a blank.

A. Identity of Problem

The problem is set up to simulate the problem that occurs in RBC at low hydraulic loading rates, warm temperatures, sufficient initial alkalinity to allow good nitrification to occur.

B. Effect and Symptoms of Problem

The trainees should recognize or be led to recognize the deleterious effect that occurs if sufficient alkalinity isn't available for nitrification. The result is a pH drop and sloughing of the culture from the discs.

C. Proposed Methods of Correction

The recommended solution to the problem would be :

1. The addition of alkalinity, for example, the addition of lime or sodium bicarbonate.
2. Could take some RBC units off line to

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDES

increasing loading to other units and take system out of nitrification.

X. Summary and Conclusion (5 minutes)

  A. Briefly summarize fixed media system operations and the use of the Process of Troubleshooting to approach operational problems.

  B. Call for any student questions, comments or discussion.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 5: Fixed Media Biological Systems

Lesson 2: Applying the Process of Troubleshooting

Trainee Notebook Contents

Troubleshooting Problem

Answer Sheets 1 - 3 . . . . T5.2.1
Problem #4 . . . . T5.2.4
Problem #4 - Design Data and Flow Diagram . . . T5.2.5
Problem #4 - Laboratory Results T5.2.6
Answer Sheet #4 . . . . T5.2.7
References T5.2.8

Troubleshooting Problem
Fixed Media Biological Systems

ANSWER SHEET

GROUP NUMBER: ____ DISCUSSION LEADER: ____________ PROBLEM NUMBER: ____

A. STATEMENT OF PROBLEM

B. LIKELY CAUSES

C. EXPECTED EFFECTS AND SYMPTOMS

D. PROPOSED METHODS OF CORRECTION

Troubleshooting Problem
Fixed Media Biological System

ANSWER SHEET

GROUP NUMBER: ___ DISCUSSION LEADER: ___________ PROBLEM NUMBER: ___

A. STATEMENT OF PROBLEM

B. LIKELY CAUSES

C. EXPECTED EFFECTS AND SYMPTOMS

D. PROPOSED METHODS OF CORRECTION

Troubleshooting Problem
Fixed Media Biological Systems

ANSWER SHEET

GROUP NUMBER: ____ DISCUSSION LEADER: ____________ PROBLEM NUMBER: ____

A. STATEMENT OF PROBLEM

B. LIKELY CAUSES

C. EXPECTED EFFECTS AND SYMPTOMS

D. PROPOSED METHODS OF CORRECTION

Troubleshooting Problem

Fixed Media Biological Systems

Problem #4

Description of Problem:

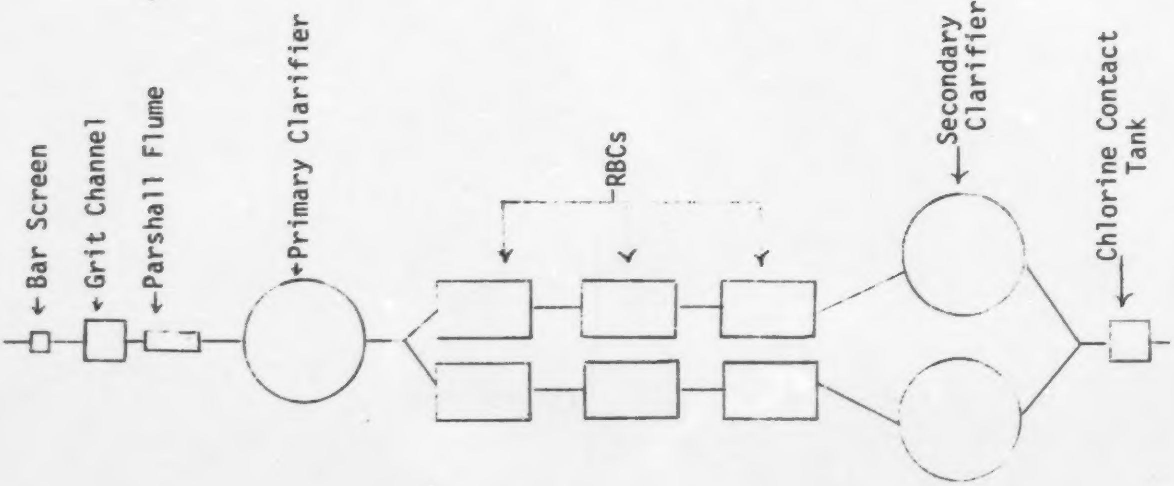
You are called by the operator of an RBC plant in a small university town. His plant usually averages 1.0 MGD flow during the year except during the summer term: June, July and August. During the summer term the flow drops to about 0.5 MGD. The problem he has is that in May, his plant was running fine as evident in the lab results below. When the summer session began and the flows dropped, things got even better. Then suddenly, the effluent just got all messed up. The BOD, suspended solids, chlorine demand and ammonia-nitrogen went up and the pH went down. The downstream part of the bio-disc units turned white and began to slough off. The operator wants to know what caused it. He says there is no industry in the town, so it can't be toxicity. Also, he hasn't been supernating from his digester.

So you go out and pick up his design information and influent and effluent lab data. You also see that his primary clarifier seems to be operated properly.

Looking at the lab data and design information, can you figure out what the problem is?

Problem #4 - Design Data

Population Equivalent	10,000
BOD$_5$ Loading	1,670 #/day
Suspended Solids	2,000 #/day
Average Daily Flow	1.0 MGD
Peak Flow	2.99 MGD
Primary Clarifier	
Capacity	70,000 gal
Detention Time	1.5 hr @ 1.0 MGD
Surface Settling Rate	895 gpd/ft^2
Bio Disk Units (2 parallel paths - 3 shafts each)	
Detention Time	90 min
Hydraulic Loading	1.94 gpd/ft^2
Secondary Clarifier - 2 units	
Detention Time	2.75 hr
Surface Overflow Rate	620 gpd/hr^2
Chlorine Contact - 2 tanks	
Detention Time	35 min



Flow Diagram

T5.2.5

Problem #4 - Laboratory Results

	END OF MAY		MIDDLE OF JUNE	
	Influent	Effluent	Influent	Effluent
Flow	1.0 MGD	1.0 MGD	0.5 MGD	0.5 MGD
BOD_5	200 mg/l	10 mg/l	200 mg/l	50 mg/l
Suspended Solids	300 gm/l	15 mg/l	230 mg/l	60 mg/l
pH	6.9	6.7	7.3	5.0
Alkalinity	320 mg/l	50 mg/l	200 mg/l	0 mg/l
Ammonia-Nitrogen	35 mg/l	5 mg/l	33 mg/l	10 mg/l
Chlorine Feed Rate		7-8 mg/l		20 mg/l

Troubleshooting Problem
Fixed Media Biological Systems

ANSWER SHEET

GROUP NUMBER: ____ DISCUSSION LEADER: ____________ PROBLEM NUMBER: ____

A. STATEMENT OF PROBLEM

B. LIKELY CAUSES

C. EXPECTED EFFECTS AND SYMPTOMS

D. PROPOSED METHODS OF CORRECTION

REFERENCES

1. Clark, J. W., Viessman, W., Jr., and Hammer, M. J., *Water Supply and Pollution Control*, International Textbook Company, 2nd Edition (1971).

2. DeRuitar, H., "Control of Psychoda Flies," *Water and Sewage Works*, *107*, 211, 1960.

3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, Municipal Operations Branch, U. S. Environmental Protection Agency, Washington, D.C.

4. Hanumanulu, V., "Effect of Recirculation on Deep Trickling Filter Performance," *Journal Water Pollution Control Federation, 41*, 1803, 1969.

5. Hawkes, H. A. and Shephard, R. N., "The Effect of Dosing Frequency on the Seasonal Fluctuations and Vertical Distribution of Solids and Grazing Fauna in Sewage Percolating Filters," *Water Research*, *6*, 721, 1972.

6. *Manual of Instruction for Sewage Treatment Plant Operators*, New York State Department of Health, Distributed outside of New York State by Health Education Service, P. O. Box 7283, Albany, New York 12224.

7. *Manual of Wastewater Operations*, Texas Water Utilities Association, Lancaster Press, Inc., 4th edition (1971).

8. *Manual of Wastewater Treatment Plants*, *MOP 11*, Water Pollution Control Federation, Washington, D.C. (1976).

9. *Operation of Wastewater Treatment Plants, A Field Study Training Program*, California State University, Sacramento, California (1970).

10. *Process Control Manual for Aerobic Biological Wastewater Treatment Facilities*, Municipal Operations Branch, U. S. Environmental Protection Agency, Washington, D.C. (March, 1977).

11. *Process Design Manual for Upgrading Existing Wastewater Treatment Plants*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (October, 1974).

12. *Wastewater Engineering: Collection, Treatment, Disposal*, Metcalf & Eddy, Inc., McGraw-Hill Book Company (1972).

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 6: Oxidation Lagoons

Unit 6 of 15 Units of Instruction

Lessons in Unit: 2 Recommended Time: 2½ hours

Instructor Overview of the Unit

Rationale for Unit: Wastewater stabilization ponds are widely used in smaller, rural communities as the cost effective secondary treatment options. Although stabilization ponds are somewhat limited in their operational flexibility, a knowledgeable troubleshooter can frequently identify O & M related problems and offer meaningful recommendations and alternatives to improve the operational efficiency of pond systems. The problem solving exercise in this unit stresses construction of minor facility modifications using available resources as a troubleshooting option to solve design related problems.

Trainee Entry Level Behavior: The trainee should have completed Unit of Instruction 2, *Elements of Troubleshooting* before beginning this Unit.

Trainee Learning Objectives: At the conclusion of this unit, the trainee should be able to:

1. From memory, list and describe the principal characteristics of stabilization ponds, their expected performance and normal operational procedures.
2. From memory, list the uncontrollable factors in operating stabilization ponds.
3. From memory, recognize and explain problem indicators and visual observations necessary for troubleshooting stabilization ponds.
4. From memory, list and explain tests and analyses for troubleshooting stabilization ponds.
5. Using references, list and identify the most common problems in operating stabilization ponds.
6. Using references, list and explain corrective actions to be implemented to solve operational problems with stabilization ponds.

7. From memory, describe the Process of Troubleshooting as applied to stabilization ponds.

8. Using references, list the means of upgrading stabilization pond performance.

9. From memory, describe seasonal operating strategies recommended for multiple stage stabilization ponds.

10. From memory, list and explain the major characteristics of aerated lagoons and contrast aerated lagoon operation to operation of unaerated stabilization ponds.

11. Demonstrate his/her ability to follow a systematic approach in solving an operational problem in stabilization ponds by applying the elements in the Process of Troubleshooting.

12. Determine which observations, data and other information are needed to apply the troubleshooting process to solving operating problems in stabilization ponds.

13. Identify and describe the nature of a specific operating problem in stabilization ponds given detailed design and operating factors, visual observations and test analyses.

14. Determine the likely cause of a specific operating problem in stabilization ponds given detailed design and operating factors, visual observations and test analyses.

15. Recommend alternative actions for immediate and long range solutions to a specific operating problem with stabilization ponds.

16. Demonstrate his/her ability to work effectively with other members of his/her work group in achieving objectives 11 - 15.

17. Demonstrate an ability to report orally his/her group's findings to the class and defend the group's findings and recommendations.

18. Compare the approach of his/her group to solution of the problem in stabilization ponds to the approaches presented by others.

19. Compare and evaluate alternative approaches to troubleshooting a problem in the operation of a stabilization pond and select the most appropriate approach and the best solution from among those presented by the class.

Sequencing and Pre-Course Preparation for the Unit: This Unit of Instruction is presented as two lessons:

Lesson 1: Troubleshooting Oxidation Lagoons

Recommended Time: 60 minutes

Purpose: Stabilization ponds are a widely used form of secondary wastewater treatment. Stabilization ponds are a common wastewater treatment system in small rural communities. Many pond systems are operated by part-time staff because of their relatively simple operation and maintenance requirements. For these reasons, the operator of the stabilization pond system may be poorly equipped to respond to problem situations which require non-routine operational controls. Technical assistance may be needed when problems occur and troubleshooters must have a basic understanding of stabilization pond operations and maintenance.

Training Facilities:

1. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees.
2. Instructor table with lectern.
3. Large projection screen (6' x 6' minimum) and chalkboard in front of room and readily visible to all trainees.
4. Easel with pad.
5. 35mm carousel projector with remote control changer at instructor table.
6. At least four empty carousel trays.
7. Overhead projector.
8. Chalk, felt-tip markers, erasers, etc.
9. Six to eight chairs randomly spaced at back and sides of room for visitors.

Pre-Course Preparation:

1. Trainee texts:

   Order and have available at each trainee seating position *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA 430/9-78-001, Municipal Operations Branch, U. S. Environmental Protection Agency, Washington, D.C. (January, 1978).

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, page T6.1.1, "Schematic Plan and Section of Typical Waste Stabilization Lagoon."

   b. *Trainee Notebook*, page T6.1.2, "Seasonal Sequencing of Flow Pattern in Two-Stage Waste Stabilization Lagoons."

3. Trainee Handout materials

   Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plans.

   a. None required for Lesson 1.

Instructional Approach: Illustrated lecture.

Lesson 2: Applying the Process of Troubleshooting

Recommended Time; 90 minutes

Purpose: This lesson provides trainees an opportunity to apply the Process of Troubleshooting to a lagoon system which is experiencing performance problems because it is both under-designed and is short-circuiting. The solution to the problem stresses use of innovative approaches to apply locally available materials to modify the pond to minimize the effects of the problem on effluent quality.

Training Facilities: As specified for Lesson 1.

Pre-Course Preparation:

1. Trainee Texts

   a. As specified for Lesson 1

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, pages T6.2.1 - T6.2.6, "Troubleshooting Oxidation Lagoons, Stages 1 - 3."

   b. *Trainee Notebook*, page T6.2.7, "References."

3. Trainee Handout materials

Reproduce the following materials from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plans.

a. None required for Lesson 2.

Instructional Approach: Trainee problem solving in groups of four and discussion of findings.

Presentation Options for the Course Director: The Unit of Instruction on Oxidation Lagoons should be presented when a significant number of course attendees will have occasion to troubleshoot stabilization pond systems. Otherwise, the unit should be deleted from the course.

Lesson 1: Troubleshooting Oxidation Lagoons provides a review of lagoon operations, maintenance and common problems. Lesson 1 alone may be sufficient to satisfy more limited troubleshooting course objectives in areas where pond systems are not commonly used for wastewater treatment.

The Unit emphasizes seasonal discharge lagoon operations with only a very limited discussion of aerated lagoons. For areas where aerated or continuous discharge lagoon systems predominate, it may be necessary to modify the unit to address local needs.

Lesson 2: Applying the Process of Troubleshooting is optional.

Summary of Unit of Instruction 6: Oxidation Lagoons

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
1. Troubleshooting Oxidation Lagoons	1. Describe lagoon properties and characteristics	1. Lagoon characteristics	1. Follow subject outline	1. Slides 179.2/6.1.1 - 179.2/6.1.47
60 minutes	2. Recognize and identify lagoon problems	2. Trouble indicators	2. Use prepared slide series	2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 100 - 109
	3. List problem causes	3. Tests and analyses	3. Seek student input in following outline	3. *Trainee Notebook*, pages T6.1.1 - T6.1.2
	4. Know corrective actions for lagoon problems	4. Troubleshooting Guide		4. *Instructor Notebook*, pages 6.1.1 - 6.1.16
	5. Identify means of upgrading lagoons	5. Methods of upgrading lagoons		
2. Applying the Process of Troubleshooting 90 minutes	1. Follow systematic approach to solving lagoon problems	1. Students are presented a realistic problem in lagoon operation which they must approach, think through and solve	The assigned problem has three stages in which the students must: 1. Decide how to approach the problem.	1. *Trainee Notebook*, pages T6.2.1 - T6.2.6, "Problem Answer Sheets"

Summary of Unit of Instruction 6: Oxidation Lagoons (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
	2. Determine troubleshooting data, nature of problem and likely cause.	2. Stress the systematic approach to troubleshooting lagoon problems	2. Determine what the problem is	2. *Instructor Notebook*, pages 6.2.1 - 6.2.7
	3. Recommend actions to correct lagoon operating problem	3. Stress the need to talk and work with people on solving problems	3. Recommend problem corrections. Trainees work in predetermined groups	3. *Field Manual for Performance Evaluation a* *Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 100 - 109
	4. Compare approaches to assigned problem, and consider the merits of alternative approaches		4. Maximum student discussion of problem assigned in Lesson 2. Lesson outline provided to guide class discussion	

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 6: Oxidation Lagoons

Lesson 1: Troubleshooting Oxidation Lagoons

Lesson 1 of 2 lessons Recommended Time: 60 minutes

Purpose: Stabilization ponds are a widely used form of secondary wastewater treatment. Stabilization ponds are a common wastewater treatment system in small rural communities. Many pond systems are operated by part-time staff because of their relatively simple operation and maintenance requirements. For these reasons, the operator of the stabilization pond system may be poorly equipped to respond to problem situations which require non-routine operational controls. Technical assistance may be needed when problems occur and troubleshooters must have a basic understanding of stabilization pond operations and maintenance.

Trainee Entry Level Behavior: The trainee should have completed Unit of Instruction 2, *Elements of Troubleshooting* before beginning this Unit.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. From memory, list and describe the principal characteristics of stabilization ponds, their expected performance and normal operational procedures.
2. From memory, list the uncontrollable factors in operating stabilization ponds.
3. From memory, recognize and explain problem indicators and visual observations necessary for troubleshooting stabilization ponds.
4. From memory, list and explain tests and analyses for troubleshooting stabilization ponds.
5. Using references, list and identify the most common problems in operating stabilization ponds.
6. Using references, list and explain corrective actions to be implemented to solve operational problems with stabilization ponds.

7. From memory, describe the Process of Troubleshooting as applied to stabilization ponds.

8. Using references, list the means of upgrading stabilization pond performance.

9. From memory, describe seasonal operating strategies recommended for multiple stage stabilization ponds.

10. From memory, list and explain the major characteristics of aerated lagoons and contrast aerated lagoon operations to operation of unaerated stabilization ponds.

Instructional Approach: Illustrated lecture.

Lesson Schedule: Within the 60 minute time period, the following schedule should be observed in presenting the lesson plan outline:

TIME	SUBJECT
0 - 10 minutes	Characteristics of Stabilization Ponds
10 - 40 minutes	Troubleshooting Stabilization Pond Problems
40 - 50 minutes	Upgrading Stabilization Ponds
50 - 60 minutes	Questions and Discussion

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, page T6.1.1, "Schematic Plan and Section of Typical Waste Stabilization Lagoon."

2. *Trainee Notebook*, page T6.1.2, "Seasonal Sequencing of Flow Pattern in Two-Stage Waste Stabilization Lagoons."

3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 100 - 109.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 6.1.1 - 6.1.16, Unit 6, Lesson 1.

2. Slides 179.2/6.1.1 - 179.2/6.1.47.

Instructor Materials Recommended for Development: None

Additional Instructor References:

1. O'Brien, W. J., McKinney, R. E., Turvey, M. D., "Two Methods for Algae Removal from Oxidation Pond Effluents, *Water and Sewage Works*, pages 66-73 (March, 1973).

2. *Upgrading Lagoons*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (August, 1973).

3. Goswani, S. R., Busch, W. H., "Three Stage Ponds Earn Plaudits," *Water and Wastes Engineering*, pp. 40-43 (April, 1972).

4. Matthew, F. L., "Operation and Maintenance of Aerobic Stabilization Ponds," *Water and Wastes Engineering*, p. 64 (July, 1968).

5. Brinck, C. W., "Operation and Maintenance of Sewage Lagoons," *Water and Sewage Works* (October, 1972).

6. Zickefoose, C. S., Hayes, R. B., *Operations Manual - Stabilization Ponds*, U. S. Environmental Protection Agency, Washington, D.C. (August, 1977).

7. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pp. 100-109, U. S. Environmental Protection Agency, Washington, D.C. (January, 1978).

8. *Stabilization Pond Operation and Maintenance Manual*, Minnesota Pollution Control Agency, Roseville, Minnesota (1979).

9. *Operation of Wastewater Treatment Plants, MOP 11*, pp. 161-182, Water Pollution Control Federation, Washington, D.C. (1976).

Classroom Set-Up:

1. Large room, preferably 40' by 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees.
2. Instructor table with lectern.
3. Large projection screen (6' x 6' minimum) and chalkboard in front of room and readily visible to all trainees.
4. Easel with pad.
5. 35mm carousel projector with remote control changer at instructor table.
6. At least four empty carousel trays.
7. Overhead projector.
8. Chalk, felt-tip markers, erasers, etc.
9. Six to eight chairs randomly spaced at back and sides of room for visitors.

LESSON OUTLINE

I. Characteristics of Stabilization Lagoons (10 minutes)

A. Lesson Objectives

1. Describe characteristics of stabilization lagoons.

2. Identify factors affecting lagoon performance.

3. Identify common problems in lagoon operations.

4. Apply the process of troubleshooting to stabilization lagoon problems.

B. Characteristics of Lagoons

1. Use Slide 179.2/6.1.3 to review lagoon characteristics.

2. Refer class to page 101, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* which illustrates treatment processes in a lagoon.

3. Visual observations tell a lot about the condition of a stabilization lagoon, such as this installation which is well-maintained.

   a. Well maintained dike

   b. Fenced

   c. Wind break

4. Compare to this poorly maintained lagoon.

   a. Excessive weeds on dike

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/6.1.1
Slide 179.2/6.1.1 is a blank.

Use Slide 179.2/6.1.2
Slide 179.2/6.1.2 is a word slide which reads:

"Troubleshooting Oxidation Lagoons"

Use Slide 179.2/6.1.3
Slide 179.2/6.1.3 is a word slide which reads:

"Characteristics of Lagoons

Natural Processes Occur Under Controlled Conditions
Reliable Treatment at Minimum Cost
Maintenance Simple But Necessary
Frequent Observation Necessary"

Use Slide 179.2/6.1.4
Slide 179.2/6.1.4 is a photograph of a well maintained lagoon showing mowed dike, fence and wind break.

Use Slide 179.2/6.1.5
Slide 179.2/6.1.5 is a photograph of a poorly maintained lagoon with

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
b. Possible evidence of burrowing animals (front, right)	excess dike week growth and some evidence of burrowing animal action on dike.
C. External Factors Affecting Lagoon Performance 1. Refer class to page 101, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*. 2. Relate elements on slide to the stabilization processes which occur in lagoons.	Use Slide 179.2/6.1.6 Slide 179.2/6.1.6 is a word slide which reads: "Uncontrollable Factors in Operating Oxidation Lagoons Visible Light Temperature Wind Ice Cover"
D. Lagoon Performance 1. Use Slide 179.2/6.1.7 to review expected performance. 2. Discuss problem of BOD test on samples which may contain large numbers of algae cells. 3. Because of algae, lagoons may have problems meeting a 30 mg/l SS effluent standard.	Use Slide 179.2/6.1.7 Slide 179.2/6.1.7 is a word slide which reads: "Expected Performance of Oxidation Lagoons Green-Clear Effluent No Scum, Grease in Effluent BOD Below 30 mg/l on Filtered Sample Algae Likely in Effluent Normally Won't Meet Secondary Effluent Requirements"
4. Use Slide 179.2/6.1.8 to illustrate clear-green color of a good lagoon system.	Use Slide 179.2/6.1.8 Slide 179.2/6.1.8 is a photograph of the clear green liquid surface of a well operated lagoon.
5. Use Slide 179.2/6.1.9 to further illustrate well operated and maintained lagoon system.	Use Slide 179.2/6.1.9 Slide 179.2/6.1.9 is a photograph showing the inlet structure and surface of a well operated and maintained lagoon. Note evidence of floating solids in foreground which probably result from anaerobic decomposition of settled bottom deposits near the inlet structure.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
6. Refer class to page 103, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* and to page T6.1.1 in the *Trainee Notebook*. a. Briefly review design and loading parameters for lagoons. b. Differentiate between oxidation ponds, facultative lagoons and aerated lagoons.	
I. Troubleshooting Lagoon Problems (30 minutes)	
A. Trouble Indicators 1. Briefly discuss points listed on Slide 179.2/6.1.10.	Use Slide 179.2/6.1.10 Slide 179.2/6.1.10 is a word slide which reads: "Trouble Indicators of Lagoons Color Changes to Dull Green, Black or Gray Unpleasant Odors Excessive Fecal Coliforms Discharged Unstable Organics are Discharged"
2. Use Slide 179.2/6.1.11 to illustrate how lagoon color and appearance can be used to spot possible problems.	Use Slide 179.2/6.1.11 Slide 179.2/6.1.11 is a photograph showing a nearly black lagoon surface with large numbers of floating solids. Possibly septic condition is illustrated.
B. Observations in Troubleshooting Lagoons 1. Refer to previous slide to illustrate importance of color. a. Clear green - good performance b. Black - possibly septic or overloaded c. Cloudy green - possible blue-green algae	Use Slide 179.2/6.1.12 Slide 179.2/6.1.12 is a word slide which reads: "Observations For Troubleshooting Lagoons Color, Important Sign of Condition Flow, Is Pond Overloaded or Short Circuited? Water Depth Aerator Performance (in Aerated Ponds) Maintenance Activity"

LESSON OUTLINE

2. Refer to page 103, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* and point out typical hydraulic and organic loadings for lagoons.

3. Normally operate facultative lagoons with a minimum of 3 feet water depth and maximum 6 feet water depth. Should vary level with season and effluent conditions to take advantage of lagoon holding capacity.

4. Aerated lagoons may go up to 20 feet deep. Need both mixing and oxygen transfer from aerators.

5. Dike maintenance, vegetation control, rodent control, inlet and outlet structure maintenance, seal intact, etc. are indicators that attempts are made to operate the lagoon.

C. Tests and Analyses

1. Use Slide 179.2/6.1.13 and have class suggest samples, tests and analyses which are needed to evaluate lagoon systems.

2. Use Slide 179.2/6.1.14 to summarize and discuss testing program for lagoons.

D. Common Problems

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/6.1.13
Slide 179.2/6.1.13 is a word slide which reads:

"Tests and Analyses for Troubleshooting Lagoons"

Use Slide 179.2/6.1.14
Slide 179.2/6.1.14 is a word slide which reads:

"Tests and Analyses for Lagoons

DO, Diurnal Variation
pH
Temperature Profile
Suspended Solids
Fecal Coliforms
Sulfides - If There are Industrial Waste Problems"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
1. Use Slide 179.2/6.1.15 to briefly review common lagoon problems. Each problem will be discussed in more detail.	Use Slide 179.2/6.1.15 Slide 179.2/6.1.15 is a word slide which reads: "Most Common Lagoon Problems Excessive Weeds, Often Related To Mosquitos Odors Short Circuiting Low DO" Refer class to pages 107-109, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* for balance of this section.
2. Weeds and mosquitos a. Use Slide 179.2/6.1.16 and have class respond to questions.	Use Slide 179.2/6.1.16 Slide 179.2/6.1.16 is a word slide which reads: "Problem: Excessive Weeds, Mosquitos Likely Cause: Things to Monitor: Corrective Action:"
b. When discussion is complete, use Slide 179.2/6/1.17 to summarize information about the problem.	Use Slide 179.2/6.1.17 Slide 179.2/6.1.17 is a word slide which reads: "Problem: Excessive Weeds, Mosquitos Cause: Poor Circulation, Maintenance Monitor: Depth, Flow Correction: Remove Weeds, Deepen Pond, Fluctuate Level"
c. Use next three slides to illustrate excessive weed problem 1) Use Slide 179.2/6.1.18	Use Slide 179.2/6.1.18 Slide 179.2/6.1.18 is a photograph showing excessive weed growth at the dike-water interface. There is also evidence of dike erosion in the center foreground.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
2) Use Slide 179.2/6.1.19	Use Slide 179.2/6.1.19 Slide 179.2/6.1.19 is a photograph which shows weed growth in the center of the lagoon. This problem was caused by a low water level which allowed light penetration to the bottom of the lagoon.
3) Use Slide 179.2/6.1.20	Use Slide 179.2/6.1.20 Slide 179.2/6.1.20 is a photograph of a lagoon in which water levels are very low (non-existent) with weed cover over the dry bottom. The problem was caused by a break in the seal liner with resultant seepage of the lagoon contents into the water table.
3. Odors a. Use Slide 179.2/6.1.21 and have class respond to questions.	Use Slide 179.2/6.1.21 Slide 179.2/6.1.21 is a word slide which reads: "Problem: Odors Likely Cause: Things to Monitor: Corrective Action:"
b. When discussion is complete, use Slide 179.2/6.1.22 to summarize information about the problem.	Use Slide 179.2/6.1.22 Slide 179.2/6.1.22 is a word slide which reads: "Problem: Odors Cause: Hydrogen Sulfide, Industrial Wastes Monitor: pH, DO, Algae, Scum, Sulfides Correction: Aeration, Prechlorination, Eliminate Septic or Industrial Inflows"
4. Short Circuiting a. Use Slide 179.2/6.1.23 and have class respond to questions.	Use Slide 179.2/6.1.23 Slide 179.2/6.1.23 is a word slide which reads: "Problem: Short Circuiting Likely Cause: Things to Monitor: Corrective Action:"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
b. When discussion is complete, use Slide 179.2/6.1.24 to summarize information about the problem.	Use Slide 179.2/6.1.24 Slide 179.2/6.1.24 is a word slide which reads: "Problem: Short Circuiting Cause: Wind Action, Hydraulic Overloading, Inlet and Outlet Locations Monitor: Flow, DO, Detention Time, Temperature Distribution Correction: Recirculate, Increase Mixing, Provide New Inlets and Outlets"
5. Low Dissolved Oxygen a. Use Slide 179.2/6.1.25 and have class respond to questions.	Use Slide 179.2/6.1.25 Slide 179.2/6.1.25 is a word slide which reads: "Problem: Low Dissolved Oxygen Likely Cause: Things to Monitor: Corrective Action:"
b. When discussion is complete, use Slide 179.2/6.1.26 to summarize information about the problem.	Use Slide 179.2/6.1.26 Slide 179.2/6.1.26 is a word slide which reads: "Problem: Low Dissolved Oxygen Cause: Industrial Waste, Detention Time, Poor Light Penetration Monitor: DO, Flow, pH, Sulfide, Loading Rate Correction: Increase Detention, Go to Parallel Operation, Aerate, Remove Weeds"
6. Dike Erosion a. Use Slide 179.2/6.1.27 and 179.2/6.1.28 to illustrate dike erosion.	Use Slide 179.2/6.1.27 Slide 179.2/6.1.27 is a photograph showing dike erosion at both high and low water levels on a lagoon. Other than erosion, the lagoon appears to be in relatively good shape.
b. Have class identify possible causes: 1) Wave action caused by wind 2) Burrowing animals	Use Slide 179.2/6.1.28

LESSON OUTLINE

c. Have class identify corrective actions

   1) Protect dike with rip-rap by extending protection at least two feet beyond low water point on dike.

   2) Wind break - should be located so that there is some wind action to aid in mixing and aerating the lagoon.

E. Summary of Lagoon Troubleshooting

   1. Briefly summarize points on Slide 179.2/6.1.32.

   2. Point out to class that although there is some operational flexibility with lagoon systems, there is not a great deal of flexibility. Therefore, the troubleshooter and operator may have to improvise a solution.

KEY POINTS & INSTRUCTOR GUIDES

Slide 179.2/6.1.28 is a photograph showing severe dike erosion in a large lagoon subject to heavy wave action caused by wind action.

Use Slide 179.2/6.1.29
Slide 179.2/6.1.29 is a photograph showing snow fencing used for dike protection. Problem with this solution is that the wooden fencing will rot and have to be replaced periodically.

Use Slide 179.2/6.1.30
Slide 179.2/6.1.30 is a photograph showing crushed stone used as a rip-rap material.

Use Slide 179.2/6.1.31
Slide 179.2/6.1.31 is a photograph showing a line of trees used as a wind break.

Use Slide 179.2/6.1.32
Slide 179.2/6.1.32 is a word slide which reads:

"Most Problems Can Be Solved With

Visual Observations
Simple Tests and Analysis
'Common Sense' Corrective Actions, i.e., Systematically Applying the Process of Troubleshooting"

Use Slide 179.2/6.1.33
Slide 179.2/6.1.33 is a word slide which reads:

"Creative Troubleshooting for Lagoon Involves:

A 'Hands-On' Approach
Using Spare Materials and Equipment
Innovative 'Jury Rigging" to Achieve Results"

LESSON OUTLINE

3. Use Slide 179.2/6.1.34 to illustrate "jury-rigging" by use of a portable pump to recirculate a lagoon system.

II. Upgrading Oxidation Ponds (15 minutes)

A. EPA reports indicate that:

1. Single cell ponds can't meet EPA 30/30 requirements.

2. Many ponds are not performing up to design standards.

3. Therefore, upgrading of ponds is often an attractive alternative.

B. Upgrading Alternative

1. Use Slide 179.2/6.1.35 and review upgrading alternatives.

2. Note that this course will address improving pond operations as a preferred soultion.

C. Improved Operations

1. Prevent short circuiting by using proper inlet distribution or adding baffles to inlets and outlets.

2. Operate flexibly

a. Allow water level to vary to take advantage of pond storage capacity.

b. Lower water level in spring, fall when effluent is good

c. Increase water level in summer and winter when effluent is bad.

3. Prevent organic overloads

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/6.1.34

Slide 179.2/6.1.34 is a photograph showing a portable pump in use to recirculate a lagoon system.

Use Slide 179.2/6.1.35

Slide 179.2/6.1.35 is a word slide which reads:

"Upgrading Alternative, In Order Of Effectiveness

Improve Operations, Minor Modifications
Modify Operating Mode
Modify Design"

Use Slide 179.2/6.1.36

Slide 179.2/6.1.36 is a word slide which reads:

"Upgrading Lagoons Through Improving Operations

Prevent Short Circuiting
Operate Inlets and Outlets Flexibility
Prevent Organic Overloads
Eliminate Weeds, Improve Maintenance"

LESSON OUTLINE

   a. Distribute load between cells if possible.

   b. Industrial waste control

  4. Maintain the pond.

D. Modify Operations

  1. Add supplemental air

  2. Use mode change in multi-cell ponds

   a. Summer operations

    1) Operate cells in series.

    2) Raise level to maximum operating depth by reducing discharge when algae are bad.

   b. Fall operations

    1) Continue series operation while weather is warm.

    2) Switch to parallel operation when temperatures fall

KEY POINTS & INSTRUCTOR GUIDES

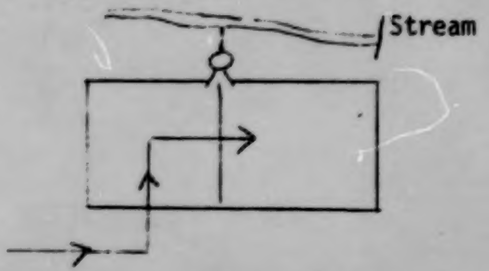
Use Slide 179.2/6.1.37
Slide 179.2/6.1.37 is a word slide which reads:

"Upgrading Lagoons Through
Modifying Operations

Supplemental Aeration
Develop Seasonal Flow Patterns
for Two Stage Pond System"

Refer class to page T6.1.2 in *Trainee Notebook.*

Use Slide 179.2/6.1.38
Slide 179.2/6.1.38 is a schematic:



Summer (July, August, September)
1. Flow Pattern: Series
2. Depth: 5 feet

Use Slide 179.2/6.1.39
Slide 179.2/6.1.39 is a schematic:

LESSON OUTLINE

3) Discharge to lower level to minimum operating depth after algae die off and effluent is clear.

c. Winter Operation

1) Parallel operations

2) Allow water level to rise to maximum operating depth and store poorly treated waste as long as possible.

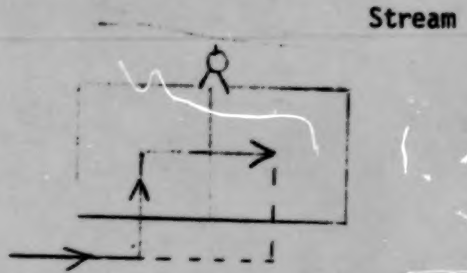
d. Spring Operation

1) Discharge after spring thaw before heavy algae build-up to lower water level to minimum operating level.

2) Switch to series operation in late spring.

3) Raise operating depth to maximum when algae begin to increase by reducing discharge.

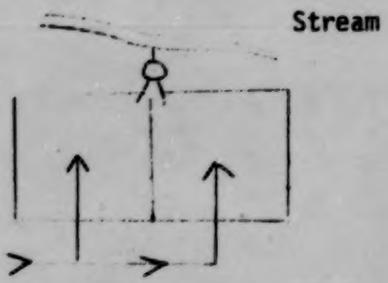
KEY POINTS & INSTRUCTOR GUIDES



Fall (October, November, December)
1. Flow Pattern: Oct., Nov.,- Series; Dec. - Parallel
2. Depth: Lower to 2½ - 3 feet
3. Effluent: Shut off (Dec.)

Use Slide 179.2/6.1.40

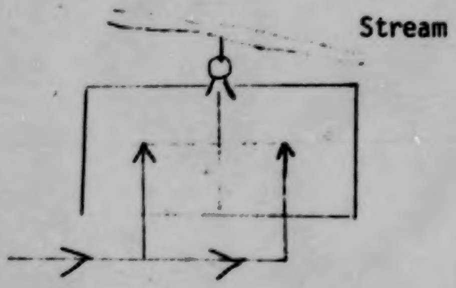
Slide 179.2/6.1.40 is a schematic



Winter (January, February, March)
1. Flow Pattern: Parallel
2. Effluent: Off (Hold All Flow)

Use Slide 179.2/6.1.41

Slide 179.2/6.1.41 is a schematic:



Spring (April, May, June)
1. Flow Pattern: Apr., May - Parallel, June - Series
2. Depth: 5 feet

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
E. Modify Design 1. Briefly discuss points on Slide 179.2/ 6.1.42. 2. Note that these are long term solutions which may be beyond the scope of a typical troubleshooting project.	Use Slide 179.2/6.1.42 Slide 179.2.6.1.42 is a word slide which reads: "Upgrading Lagoons Through Modifying Design Polishing Techniques, Rock and Sand Filters Add Capacity, Additional Cells Add Flexibility, Inlets, Outlets Go to Full Time Mechanical Aeration"
F. Aerated Lagoons 1. "Activated sludge" which operates at long detention time, low F/M and low MLSS concentration. 2. Secondary cell or an unaerated portion of aerated cell serves as settling tank. 3. Some systems circulate from the final cell back to the aerated cell. 4. Aerators provide both air and mixing. Not dependent on algae as oxygen source.	Use Slide 179.2/6.1.43 Slide 179.2/6.1.43 is a word slide which reads: "Characteristics of Aerated Lagoons Actually Variation of Activated Sludge Requires a Secondary Settling Depths of 10 Feet to 20 Feet Use Surface Aerators or Diffused Air Aerators Must be Properly Secured"
5. Illustrations of aerated lagoons a. Diffused air system 1) Diffusers being installed	Use Slide 179.2/6.1.44 Slide 179.2/6.1.44 is a photograph which shows diffuser array in an empty lagoon.
2) Diffused air lagoon	Use Slide 179.2/6.1.45 Slide 179.2/6.1.45 is a photograph showing the diffused air lagoon in operation.
b. Surface mechanical aerator 1) Possible freeze-up 2) Must anchor aerators	Use Slide 179.2/6.1.46 Slide 179.2/6.1.46 is a photograph of a lagoon fitted with surface mechanical aerators.

LESSON OUTLINE

IV. Discussion and Questions (5 minutes)

Use any remaining time for questions and discussion.

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/6.1.47
Slide 179.2/6.1.47 is a blank.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 6: Oxidation Lagoons

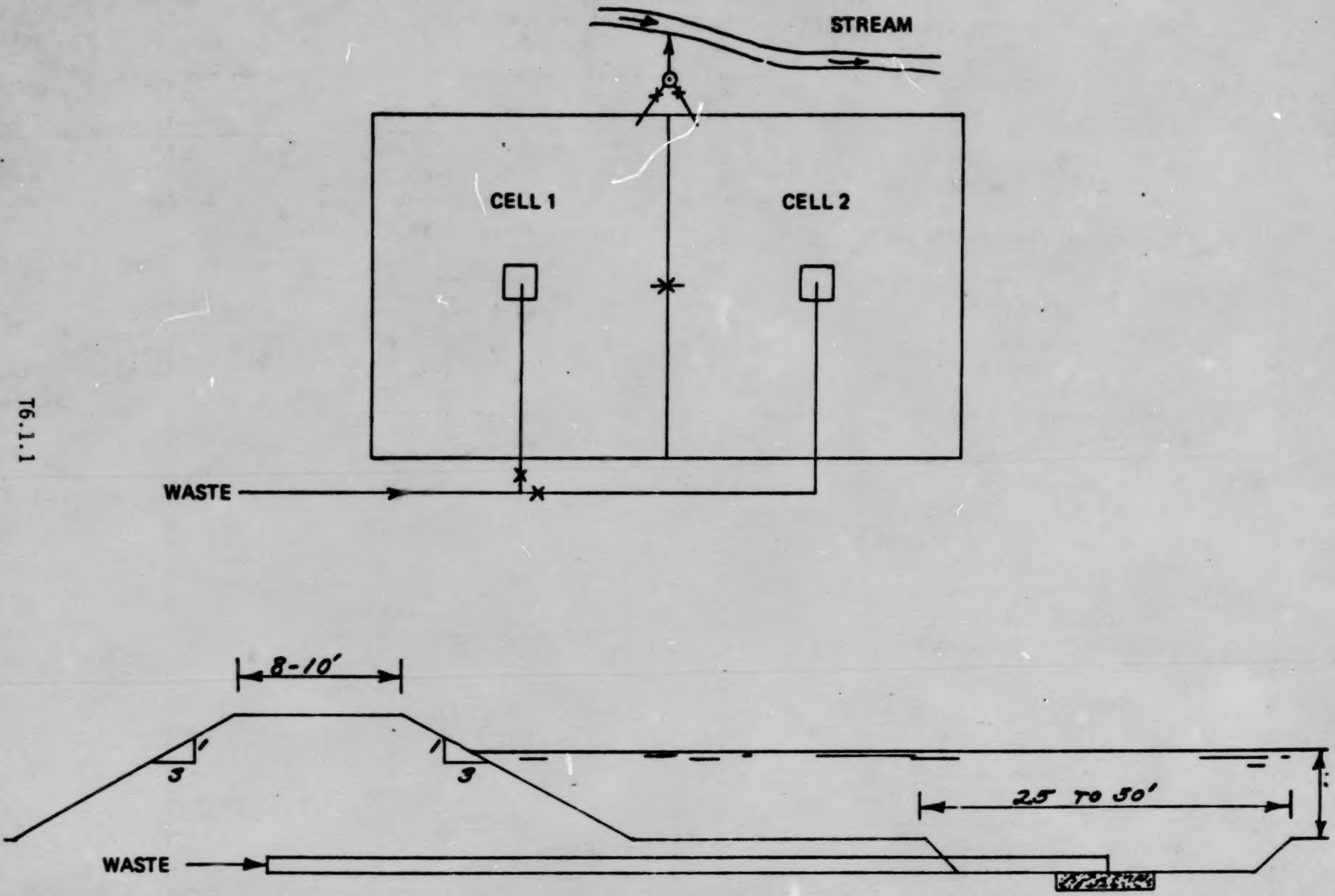
Lesson 1: Troubleshooting Oxidation Lagoons

Trainee Notebook Contents

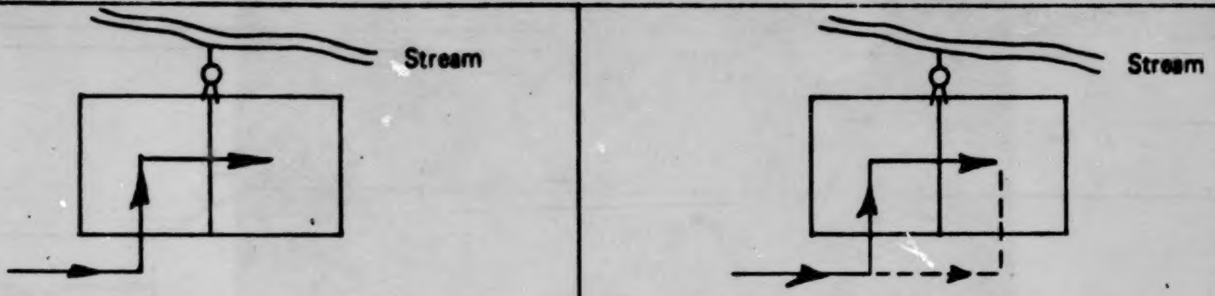
Schematic Plan and Section of Typical
Waste Stabilization Lagoon T6.1.1

Seasonal Sequencing of Flow Pattern in Two-Stage
Waste Stabilization Lagoon T6.1.2

T6.1.1

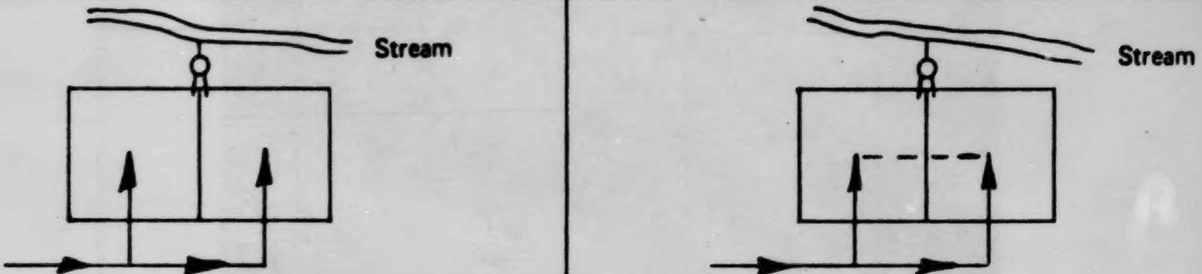


SCHEMATIC PLAN AND SECTION OF TYPICAL WASTE STABILIZATION LAGOON



SUMMER (July, August, September)
1. Flow Pattern: Series
2. Depth: 5 ft

FALL (October, November, December)
1. Flow Pattern:
Oct., Nov. – Series
Dec. – Parallel
2. Depth: Lower to 2½ – 3 ft
3. Effluent: Shut off (Dec.)



WINTER (January, February, March)
1. Flow Pattern: Parallel
2. Effluent: Off
(Hold All Flow)

SPRING (April, May, June)
1. Flow Pattern:
Apr., May Parallel
June - Series
2. Depth: 5 ft

SEASONAL SEQUENCING OF FLOW PATTERN IN TWO-STAGE WASTE STABILIZATION LAGOONS

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 6: Oxidation Lagoons

Lesson 2: Applying the Process of Troubleshooting

Lesson 2 of 2 lessons Recommended Time: 90 minutes

Purpose: This lesson provides trainees an opportunity to apply the Process of Troubleshooting to a lagoon system which is experiencing performance problems because it is both underdesigned and is short-circuiting. The solution to the problem stresses use of innovative approaches to apply locally available materials to modify the pond to minimize the effects of the problem on effluent quality.

Trainee Entry Level Behavior: The trainee should have achieved the learning objectives specified for Unit 6, Lesson 1, before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee should be able to:

1. Demonstrate his/her ability to follow a systematic approach in solving an operational problem in stabilization ponds by applying the elements of the process of troubleshooting.
2. Determine which observations, data and other information are needed to apply the troubleshooting process to solving operating problems in stabilization ponds.
3. Identify and describe the nature of a specific operating problem in stabilization ponds given detailed design and operating factors, visual observations and test analyses.
4. Determine the likely cause of a specific operating problem in stabilization ponds given detailed design and operating factors, visual observations and test analyses.
5. Recommend alternative actions for immediate and long range solutions to a specific operating problem with stabilization ponds.
6. Demonstrate his/her ability to work effectively with other members of his/her work group in achieving objectives 1 through 5.
7. Demonstrate an ability to report orally his/her group's findings to the class and defend the group's findings and recommendations.

8. Compare the approach of his/her group to solution of the problem in stabilization ponds to the approaches presented by others.

9. Compare and evaluate alternative approaches to troubleshooting a problem in the operation of a stabilization pond and select the most appropriate approach and the best solution from among those presented by the class.

Instructional Approach: Trainee problem solving in groups of four and discussion of findings.

Lesson Schedule: The 90 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 5 minutes	Introduce the Problem
5 - 25 minutes	Complete Stage 1 of the Problem
25 - 45 minutes	Complete Stages 2 and 3 of the Problem
45 - 60 minutes	Discuss Stage 1 Findings
60 - 70 minutes	Discuss Stage 2 Findings
70 - 80 minutes	Discuss Stage 3 Findings
80 - 90 minutes	General Discussion of Problem and Trainee Approach to Problem Solving

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T6.2.1 - T6.2.6, "Troubleshooting Oxidation Lagoons, Stages 1 - 3."

2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 100-109.

3. *Trainee Notebook*, page T2.2.8, "The Process of Troubleshooting."

4. *Trainee Notebook*, page T6.2.7, "References."

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 6.2.1 - 6.2.7 , Unit 6, Lesson 2.

2. *Trainee Notebook*, pages T6.2.1 - T6.2.6, "Troubleshooting Oxidation Lagoons, Stages 1 - 3."

Instructor Materials Recommended for Development: None

Additional Instructor References: As specified in Unit 6, Lesson 1.

Classroom Set-Up: As specified in Unit 6, Lesson 1.

Instructor Introduction to the Lesson:

1. Trainees are to be arranged in four person work groups. Each trainee is expected to participate fully in the gourp discussion to analyze and solve the assigned problem.

2. The problem is presented in three stages, as reflected in the problem/answer sheets as follows:

   a. First Stage: *Trainee Notebook*, pages T6.2.1 - T6.2.2. Trainees are given Stage 1 which contains very little information, only that there is a 2-pond stabilization system which has been operating sporadically with variable results. Trainee groups are to fill out the first answer sheet which requires them to describe how they will approach the problem.

   b. Second Stage: *Trainee Notebook*, pages T6.2.3 - T6.2.4. After 20 minutes, trainee groups move to Stage 2 which contains data obtained by observing, testing and analyzing the plant. In the second stage, trainees are to identify the problem (it is one of short circuiting and inadequate detention time) and its causes. Once this is determined, they check with the instructor (one group at a time) before proceeding to the third stage.

   c. Third Stage: *Trainee Notebook*, pages T6.2.5 - T6.2.6. Trainee groups are to recommend possible corrective actions for the problem and spell out how they would verify that the problem has been corrected.

3. As the trainee groups complete stage two, the instructor should meet with them and give them enough assistance to allow them to go on to Stage 3, i.e., make sure each group is on the right track.

4. The instructor should announce at the start of the subdivision that trainees may refer to the EPA manual *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pp. 100-109. but it is preferred that they try to solve the problem without unnecessary use of permitted references.

5. The instructor should review the recommended solutions to each problem stage, Roman Numerals VII - IX, page 6.2.5 - 6.2.7 , before the session begins and periodically consult with trainee work groups to guide them toward the solutions.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
I. Prior to Start of Lesson Subdivision	
A. Trainee groups should be designated by Course Director or instructor	
B. Problem statements are included in the *Trainee Notebook* as pages T6.2.1 - T6.2.2.	
II. Introduction to Lesson Subdivision	Guide: Allow 5 minutes to introduce the problem
A. Refer class to *Trainee Notebook*, pages T6.2.1 and T6.2.2, "Troubleshooting Oxidation Lagoons, Stage 1."	
B. Introduce problem and describe Stage 1.	
III. Stage 1	Guide: Allow 20 minutes for trainees to complete Stage 1.
A. Instructor should circulate from group to group to answer questions where necessary.	
B. As groups complete Stage 1, start them on Stages 2 and 3.	
IV. Stage 2	Guide: Allow 10 minutes for trainees to complete Stage 2.
A. Refer class to *Trainee Notebook*, pages T6.2.3 and T6.2.4, "Troubleshooting Oxidation Lagoons, Stage 2."	
B. After 5 minutes check group findings, i.e., have they identified the problem? If so, let them go on to the third stage, *Trainee Notebook*, pages T6.2.5 and T6.2.6, "Troubleshooting Oxidation Lagoons, Stage 3."	
V. Stage 3	Guide: Allow 10 minutes for trainees to complete Stage 3.
A. For any group that has not completed the second stage satisfactorily within a 10 minute period, give them enough assistance to move on to the third stage.	
B. Instructor should remain available to answer questions.	
C. Call time at the end of 45 minutes and move on to Problem Reporting and Analysis.	Guide: No more than 45 minutes should be allowed to complete actions II - V.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
VI. Generate Comments and Discussion from Class Regarding the Assigned Problem	Guide: Use as opening to "warm up" for discussion (5 minutes)
VII. Answers to Problem Stage 1	Guide: Use 10 minutes for reporting.
A. Who to talk to: plant operator, other plant personnel, any other possible observers of past plant performance.	Key Point: Stress systematic approach.
B. Information: design capacity, hydraulic and organic load, detention time.	Stress the need to talk to people and get needed information
C. In Records: flow records, NPDES monitoring records and any in-plant process testing records, records of complaints if they are kept.	
D. References: O & M manual, if there is one. EPA manual *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, and *Operations Manual: Stabilization Ponds*.	
E. Questions	
1. Describe normal operations, normal effluent quality and pond properties.	
2. Recent occurrences: ask questions to learn what has taken place leading up to present conditions.	
F. Parameters sampled: minimum - pond and effluent pH, DO, suspended solids and temperature gradient. (Interestingly, the two EPA manuals differ on what should be sampled.)	
G. Visual Observations:	
1. Color: deep green is good, gray or black is bad.	
2. Wind direction	
3. Scum at outlet	
VIII. Answers to Problem Stage 2	Guide: Use 10 minutes for reporting.
A. Regardless of how the troubleshooter expresses it, the problem is one of inadequate	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
detention time, caused by short circuiting. Pond is under designed.	Key Point: Analyze available information to determine possible causes of plant problem.
B. Possible causes of the problem	List alternatives until the most likely cause is found.
1. Parallel rather than series operation of two ponds.	
2. Recent hydraulic overload	
3. Wind direction	
4. Location of inlet and outlet	
5. Inflexibility of plant - prevents operator from making adjustments due to weather and hydraulic conditions	
6. Thermal stratification within the lagoons	5-6 degree difference
7. Lagoons are too small	
IX. Answers to Problem Stage 3	Guide: Use 10 minutes for reporting
A. Actions to take 1. Immediate a. Change to series operation	Key Point: Actions can be taken to immediately correct plant problems. Other actions can be taken to prevent recurrences and to upgrade overall plant performance.
b. Use pumps and hose or pipe to recirculate within lagoons to prevent short-circuiting	Stress importance of follow-up and of documenting the results of the troubleshooting actions.
c. Skim outlet to remove scum	
d. Create other means to achieve better mixing	Increase depth
2. Long Range	
a. Use available earth moving equipment and wood to construct additional outlets, allowing for variable discharge depth.	
b. Construct additional inlets	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
c. Install floating scum baffles at outlets	
d. Erect baffling and other mixing devices to gain maximum detention time	Aerate 1st cell Operate 2nd cell as batch with polyelectrolytes
B. Sampling and Testing - standard process control plus effluent monitoring tests	
pH, DO, suspended solids, temperature	
C. Follow-up periodically, perhaps monthly or quarterly, with a phone call. Review NPDES monitoring reports.	
X. Summarize - Application of the Key Elements of Troubleshooting to the Problem	Guide: Use 10 minutes
A. Developing a relationship with plant operator	Key Point: Systematic approach to troubleshooting and problem solving.
B. Obtaining and analyzing needed information	
C. Formulating alternatives	
D. Observing the results of corrective actions	
E. Long-range implementation and follow-up	

what we are used to (pomp came later, with the Imperial Church); but nothing touched by the spirit of Rome would have been undignified; though in Gaul, say, they might have been less solemn.

After the Lord's Supper, the congregation would probably share what we should call a potluck breakfast - wine, bread, cheese, olives, fruit.

This would have been in time of peace. Three times in the third century, Christians' peace was interrupted. Persecutions had happened in earlier times, but before the late second century, most persecutions had been short, violent episodes of local lynch mobs or the tantrums of mad-men such as Nero or Domitian. Now, however, the formidable organizations of Roman law, bureaucracy, and army were geared systematically to eliminate "impious and atheist" Christians from Roman society. Thrice in the century (under Marcus Aurelius and Septimius Severus at the beginning, Decius in mid-century and Diocletian at the end), Christian houses of worship were closed, books and ceremonial vessels destroyed, meetings forbidden, leaders imprisoned. Every citizen was ordered to obtain a labellus, a small token which certified that he or she had participated in the state sacrifices of the imperial cult. Of course, Christians could not throw incense on the emperor's altar, so they were tried by the procurators or governors for treason and executed.

In North Africa hundreds went to the arena. Let me tell you the story of one group. In Carthage in the year 203, two women and four men were put under house arrest for going to a Christian meeting. While there, several who had not yet been baptized were washed in the saving waters. Shortly after, soldiers took them to the city jail. One of the women, a young upper class widow named Perpetua, was visited in jail by her father, who pleaded with her to renounce her novel superstition, if for no other reason, for the sake of her child; Perpetua would not abjure Christ, but she did give the child to its grandparents. When the six Christians were brought to trial, they all confessed Christianity and the Procurator condemned them "ad liones". They were returned to their cells for several weeks to await execution. During that time the other woman, a pregnant slave named Felicity, went into labor. In her pain, Felicity shrieked. The jailer laughed at her, "You scream now, wait 'til you are in the arena". A baby girl was delivered to Felicity, and permitted to be adopted by friends outside the prison. Then on March 6, 203, the prisoners were escorted to the city coliseum under the African sun. "You judge us, God will judge you", they warned the Procurator Hilarion. He signaled, the crowd screamed. The women were charged by a savage cow. The men were set upon by a leopard, a bear and a boar. They stood with gallant faces, they kissed each other, said an eyewitness, "that their martyrdom might be perfected with the rite of peace". They were mangled, but not killed. The coups de grace was delivered by a sword thrust through their throats.

"The blood of martyrs is the semen of the church", wrote Tertullian. And so it was - the Empire could not exterminate Christianity, try as it would. One hundred twenty years after Felicity died, the Christians would take over the Empire. As we shall see next week, the meek were to inherit the earth.

SW

---

1. 362 and 195 in THE HYMNAL, 1940
2. 158, Ibid.

515

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 6: Oxidation Lagoons

Lesson 2: Applying the Process of Troubleshooting

Trainee Notebook Contents

Troubleshooting Oxidation Lagoons

Stage 1 . . . . T6.2.1

Stage 2 . . . . T6.2.3

Stage 3 . . . . T6.2.5

References T6.2.7

Troubleshooting Oxidation Lagoons

Stage 1

GROUP # _____

PROBLEM: It is reported to you that a treatment facility using stabilization ponds for secondary treatment has been operating sporadically with highly variable results. At the time you are called it is operating poorly. The facility has two faculative ponds, that can be operated in series or in parallel, which serve a community of 1,200 people. There are no industrial wastes discharged into the plant.

On these answer sheets, list the actions you would take as a troubleshooter to be able to assist in solving this problem. Answer the following questions. (You may use additional paper if necessary.)

1. Who would you talk to about the performance of the plant?

2. What information would you need about the design and layout of the lagoons?

3. What records would you look at?

4. What references, texts or persons would you consult with?

5. What questions would you ask about plant operations?

6. Make a list of what you would test for and where you would sample.

Constituents	Sample Location

7. What visual observations would you make and what would you look for?

8. What other information would you need?

You have 20 minutes to complete this stage of the problem. Consult with the instructor before you proceed.

Troubleshooting Oxidation Lagoons

Stage 2

GROUP #: _____

During your investigation (Stage 1) you learn the following about the stabilization pond in question.

Design and Loading factors:

Depth: 4 feet, Design detention time: 100 days, Design loading: 20 #/acre/da
Hydraulic design capacity: 150,000 gpd
Normal operation at design capacity: Ponds in parallel
Prevailing winds: from west

Normal Operating Conditions and Performance:

BOD: Influent - 200 mg/l, Effluent - 45 mg/l
SS: Influent - 300 mg/l, Effluent - 50 mg/l
Algae Concentration: Effluent - 25 mg/l in suspension
pH: Effluent - 9.5; DO: Effluent - supersaturated, daylight hours
Color: Effluent - deep green

Conditions as of 4:00 p.m., day you arrive, after sampling and testing:

BOD: Effluent - too early to tell; SS: Effluent - 95 mg/l
Algae Concentration: Effluent - 55 mg/l in suspension
pH: Effluent - 7.3; DO: Effluent - 4.5
Temperature: Air - 65^{o}, Water at Surface - 69^{o}, Water at Bottom - 62^{o}
Coliforms: you have no immediate readings, but total effluent coliforms have risen in last 5 days to very high values

Visual Observations and Other Information Learned:

Color of Effluent: Dull green/gray, build-up of scum at outlet of ponds
Ponds are being operated in parallel
Location of inlets: northeast and southeast corners of two ponds
Location of single outlets to each pond - west side
Prior weather: abnormally high rains during previous 10 days due to a large tropical storm and local showers. Predominant winds from northeast
Flows: Measured flow at time of your arrival is 180,000 pgd. However, discussions with plant staff on weir levels during recent days indicate there were probably flows as high as 320,000 gpd due to stormwater infiltration and local flooding
Plant history: You learn that plant operates with poor removal efficiencies about 30% of the time

Stage 2 (Continued)

PROBLEM: Given the above information which you learned during your visit to the plant:

1. Identify and describe the plant's problem(s).

2. List the likely causes of the problem.

STOP! Consult with the instructor before going to Stage 3.

Troubleshooting Oxidation Lagoons

Stage 3

GROUP #: _____

PROBLEM: Having adequately identified the problem and its causes:

1. List the actions you would take to correct the plant problems.
    a. Alternative actions for immediate results (in order of priority):

    b. Long range actions to prevent a recurrence:

Note: The following are available in the community and may be used in implementing corrective actions if you choose to use them.

Two (2) portable pumps
Discarded, but usable fire hose
Lighweight plastic pipe
Assorted sizes and shapes of wood, i.e., 2 x 4's, etc.
Earth moving equipment
Small boat with outboard motor
Alum and poly-electrolytes
Portable chlorine applicator

2. What sampling and testing would you conduct once corrective action is taken? Why? How long?

Stage 3 (Continued)

3. For how long would you follow up on the plant's performance and be concerned about its effectiveness? Why? What method would you use to follow up?

References

1. Brinck, C. W., "Operation and Maintenance of Sewage Lagoons," *Water and Sewage Works*, (October, 1972).

2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pp. 100-109, U. S. Environmental Protection Agency, Washington, D.C. (January, 1978).

3. Goswani, S. R., Busch, W. H., "Three Stage Ponds Earn Plaudits," *Water and Wastes Engineering*, pp. 40-43 (April, 1972).

4. Matthew, F. L., "Operation and Maintenance of Aerobic Stabilization Ponds," *Water and Wastes Engineering*, p. 64 (July, 1968).

5. O'Brien, W. J., McKinney, R. E., Turvey, M. D., "Two Methods for Algae Removal from Oxidation Pond Effluents, *Water and Sewage Works*, pp. 66-73 (March, 1973).

6. *Operation of Wastewater Treatment Plants, MOP 11*, pp. 161-182, Water Pollution Control Federation, Washington, D.C. (1976).

7. *Stabilization Pond Operation and Maintenance Manual*, Minnesota Pollution Control Agency, Roseville, Minnesota (1979).

8. *Upgrading Lagoons*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (August, 1973).

9. Zickefoose, C. S., Hayes, R. B., *Operations Manual - Stabilization Ponds*, U. S. Environmental Protection Agency, Washington, D.C. (August, 1977).

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 7: Laboratory Practices

Unit 7 of 15 Units of Instruction

Lessons in Unit: 3 Recommended Time: 2 hours

Instructor Overview of the Unit

Rationale for Unit: A major cause for inadequate performance of wastewater treatment facilities is failure of the operator to perform adequate laboratory testing and use test results in process control decision making. Frequently, laboratories are inadequately designed, equipped and staffed to provide needed laboratory services to support plant operations and process control. The thrust of the unit is toward the process control laboratory with little discussion of the NPDES effluent monitoring program requirements. This unit of instruction focuses on techniques and procedures for evaluating the adequacy of the wastewater treatment laboratory services program and facilities.

Trainee Entry Level Behavior: The trainee should have completed Unit of Instruction 2, *Elements of Troubleshooting*, before beginning this Unit of Instruction.

Trainee Learning Objectives: At the conclusion of this unit, the trainee will be able to:

1. Describe the uses of the laboratory for process control and the Process of Troubleshooting.
2. List and describe important considerations for correct sample collection.
3. List the three main types of samples and describe their uses in plant process control and troubleshooting.
4. Point out where additional information is available that deals with sampling locations, types and frequencies for the various wastewater treatment units.
5. List and evaluate the main factors which indicate laboratory adequacy.
6. Discuss main considerations in evaluating staff composition and procedures.

7. Outline methods of evaluating laboratory facilities and equipment.
8. Outline method of evaluating laboratory test results.
9. Identify laboratory safety hazards.
10. Describe the limitations to troubleshooting laboratory problems and approach troubleshooting with a systematic approach.
11. Visually inspect a wastewater treatment plant laboratory.
12. Recognize poor or improper equipment and/or conditions which may be encountered in a wastewater treatment plant laboratory.

Sequencing and Pre-Course Preparation for the Unit: This Unit is presented as three lessons.

Lesson 1: The Laboratory as a Tool for Process Control and Troubleshooting

Recommended Time: 30 minutes

Purpose: This lesson stresses the importance of the laboratory as a tool in process control and troubleshooting by focusing on purposes and functions for gathering and maintaining laboratory data. The importance of proper sample collection and preservation is stressed.

Training Facilities:

1. Large room, preferably 40' by 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees.
2. Instructor table with lectern.
3. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.
4. Easel with pad.
5. 35mm carousel with remote control changer at instructor table.
6. At least four empty carousel trays.
7. Overhead projector.

8. Chalk, felt-tip markers, erasers, etc.

9. Six to eight chairs randomly spaced at back and sides of room for visitors.

Pre-Course Preparation:

1. Trainee Texts:

   Reproduce or purchase and make available at each trainee seating position the following:

   a. None required for Lesson 1

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. The most current *Federal Register* listing of approved laboratory procedures for NPDES monitoring and reporting.

   b. The names, addresses and telephone numbers of the U.S. EPA Region Laboratory Quality Assurance Coordinator and the state Laboratory Quality Assurance Coordinator.

   c. If the state has a laboratory certification program, the rules, regulations and procedures for laboratory certification.

3. Trainee Handout materials

   Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plans.

   a. None required for Lesson 1.

Instructional Approach: Illustrated lecture and class discussion.

Lesson 2: Troubleshooting Laboratory Practices

Recommended Time: 60 minutes

Purpose: One of the most frequently cited causes for poor wastewater treatment facility performance is inadequate laboratory testing and failure to use laboratory test results in process control decision making. This lesson stresses the importance of evaluating the laboratory and the laboratory testing program as an integral component in troubleshooting wastewater treatment facilities.

Training Facilities: As specified for Lesson 1.

Pre-Course Preparation:

1. Trainee texts

   a. None required for Lesson 2

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, page T7.2.1, "Major Steps in Troubleshooting a Laboratory Program."

3. Trainee Handout materials

   Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plans.

   a. None required for Lesson 2.

Instructional Approach: Illustrated lecture.

Lesson 3: Laboratory Equipment

Recommended Time: 30 minutes

Purpose: Review common wastewater laboratory equipment and highlight defects which can be spotted during a visual inspection of the laboratory area.

Training Facilities: As specified for Lesson 1.

Pre-Course Preparation:

1. Trainee texts

   a. None required for Lesson 3.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, page T7.3.1, "References".

3. Trainee Handout materials

Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees as called for in the lesson plans.

a. None required for Lesson 3.

Instructional Approach: Illustrated lecture with trainee discussion.

Presentation Options for the Course Director: The 120 minute Unit on *Laboratory Practices* is an important part of the overall troubleshooting approach being stressed throughout this course. The two hour time period is felt to be appropriate in relation to a total course effort of between 28 and 40 hours. If it is necessary to present this course in fewer than 28 hours then the Course Director should consider reducing this Unit in scope or eliminating it altogether. If the course is expanded beyond the 40 hours, there are several options for lengthing this unit if desired. In shorter courses the Unit can easily be contracted to a one hour presentation by selecting only one portion of each lesson for presentation.

The developers of the course believe that it would not normally be advised to expand this unit unless the trainees attending the course had a specific interest or need to better their familiarity with the laboratory. If not, it is felt that typical target trainees would more greatly benefit from expansions in other lessons. Any expansion of this Unit should include ample opportunity for *trainee participation*, inasmuch as the Unit as it now stands is primarily structured in a lecture-slide format, with less focus on trainee participation and involvement than some of the longer units. Options for presenting this unit include:

Lesson 1 - *The Laboratory as a Tool for Process Control and Troubleshooting* A section can be added to this subdivision on developing a systematic unit process testing program for a treatment plant laboratory. By using Chapter II and Appendix A of *Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities*, examples of developing process testing programs can be performed by the instructor or by the class in their designated trainee groups. If the need exists, and time permits, a period of up to four hours could be devoted to this activity. If this approach is to be used, the instructor will have to obtain and provide copies of the pertinent materials for the trainee's use.

Control Tests: If it is desired to familiarize the class with specific control tests, material from the National Training and Operational Technology Center, EPA, Cincinnati, can be utilized. These consist of material on control tests for the Activated Sludge Process prepared by A.W. West. Materials available include: Manual - *Operational Control Procedures for the Activated Sludge Process - Part II, Control Tests*, April, 1973, and a slide-tape series, Control Tests, Part II, XT-41, 17 minutes. (Available at all

EPA Regional Headquarters.) A period of up to two hours may be spent performing control tests in a laboratory in conjunction with the Laboratory Practices unit or the Activated Sludge unit. These tests are described in detail in Unit of Instruction 11: *Activated Sludge.*

Effluent Monitoring Tests: The lesson stresses process control testing rather than the NPDES effluent monitoring test requirements. The lesson could be expanded by inserting extensive discussion of effluent monitoring test procedures. The National Training and Operational Technology Center, U. S. EPA, Cincinnati, has excellent training materials available for structuring sessions on testing procedures approved for NPDES monitoring and reporting.

Laboratory Visit: If time is available, and facilities are convenient, small groups may be taken on actual visits to wastewater treatment plant laboratories. This should only be done where a specific need exists to familiarize trainees with an actual working lab.

Lesson 2 - *Troubleshooting Laboratory Practices*
This lesson can be condensed to 30 minutes by eliminating trainee discussion and presenting the lesson highlights in a lecture format. This can be accomplished by deleting all photographic slides and using only the title slides to summarize the key points related to laboratory evaluation.

Lesson 3 - *Laboratory Equipment*
This lesson is optional. It should be used when a major emphasis on detailed laboratory evaluation is desired.

Summary of Unit of Instruction 7: Laboratory Practices

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
1. The Laboratory as a Tool for Process Control and Trouble-shooting	1. Describe lab uses for process control and troubleshooting	1. Process of Trouble-shooting requires good lab analysis	1. Follow lesson outline using slides and key	1. Process of Trouble-shooting Chart, *Trainee Notebook*, page T2.2.8
30 minutes	2. Utilize sampling procedures	2. Inadequate labs have caused poor process control	2. Encourage student discussion	2. *Instructor Notebook*, pages 7.1.1 - 7.1.14
	3. Evaluate treatment	3. Troubleshooters need to know proper sampling procedures	3. Continually focus on the value of the lab for trouble-shooting and process control	3. Slides 179.2/7.1.1 - 179.2/7.1.9
2. Troubleshooting Laboratory Practices	1. Identify and evaluate factors of lab adequacy	1. Three factors which identify lab adequacy	1. Follow lesson outline, using slides and key, and *Notebook* materials	1. Slides 179.2/7.2.1 - 179.2/7.2.29
60 minutes	2. Evaluate lab staffing and procedures	2. Lab staff and procedures can be upgraded	2. Slide series should stress involvement of students in identifying the significance of what is seen on slides	2. *Trainee Notebook*, page T7.2.1
	3. Evaluate lab equipment, facilities and housekeeping	3. Lab housekeeping, maintenance and safety precautions are important indicators of lab adequacy		3. *Instructor Notebook*, pages 7.2.1 - 7.2.20

Summary of Unit of Instruction 7: Laboratory Practices (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
	4. Identify and prevent safety hazards	4. Troubleshooter attitude and behavior is important toward overcoming troubleshooting barriers		
	5. Approach lab troubleshooting constructively to overcome barriers			
3. Laboratory Equipment 30 minutes	1. To identify commonly used laboratory equipment	1. Specific laboratory equipment	1. Use slides and slide key-full discussion	1. *Instructor Notebook*, pages 7.3.1 - 7.3.6
	2. To identify favorable and unfavorable lab conditions			2. Slides 179.2/7.3.1 - 179.2/7.3.26
				3. *Trainee Notebook*, page T7.3.1

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 7: Laboratory Practices

Lesson 1: The Laboratory as a Tool for Process Control and Troubleshooting

Lesson 1 of 3 lessons | Recommended Time: 30 minutes

Purpose: This lesson stresses the importance of the laboratory as a tool in process control and troubleshooting by focusing on purposes and functions for gathering and maintaining laboratory data. The importance of proper sample collection and preservation is stressed.

Trainee Entry Level Behavior: Trainees should have completed Unit of Instruction 2: *Elements of Troubleshooting*, before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson the trainee will be able to:

1. Describe the uses of the laboratory for process control and the Process of Troubleshooting.
2. List and describe important considerations for correct sample collection.
3. List the three main types of samples and describe their uses in plant process control and troubleshooting.
4. Point out where additional information is available that deals with sampling locations, types and frequencies for the various wastewater treatment units.

Instructional Approach: Illustrated lecture and class discussion.

Lesson Schedule: The 30 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 10 minutes	Troubleshooting and Laboratory Practices
10 - 30 minutes	Guide to Sampling

Trainee Materials Used in Lesson: None.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 7.1.1 - 7.1.14, Unit 7, Lesson 1.
2. Slides 179.2/7.1.1 - 179.2/7.1.9.

Instructor Materials Recommended for Development: The Course Director should obtain, reproduce and insert into the *Trainee Notebook* the following:

1. The most current *Federal Register* listing of approved laboratory procedures for NPDES monitoring and reporting.
2. The names, addresses and telephone numbers of the U. S. EPA Region Laboratory Quality Assurance Coordinator and the state Laboratory Quality Assurance coordinator.
3. If the state has a laboratory certification program, the rules, regulations and procedures for laboratory certification.

Additional Instructor References:

1. *Standard Methods for the Examination of Water and Wastewater*, APHA, AWWA and WPCF (14th edition).
2. *Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities*, EPA 430/9-74-002, Municipal Operations Branch, U. S. Environmental Protection Agency, Washington, D.C. (June, 1973).
3. *Inspectors Guide for Evaluation of Municipal Wastewater Treatment Plants*, EPA 430/9-79-010, Municipal Operations Branch, U. S. Environmental Protection Agency, Washington, D.C. (April, 1979).
4. *Federal Register*, Guidelines Establishing Test Procedures for the Analysis of Pollutants.
5. *Operation of Wastewater Treatment Plants, MOP 11*, pages 19-36, 381-410, 463-478, 511-524, Water Pollution Control Federation, Washington, D.C. (1976).

Classroom Set-Up:

1. Large room, preferably 40' by 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees.
2. Instructor table with lectern.
3. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.

4. Easel with pad.

5. 35mm carousel projector with remote control changer at instructor table.

6. At least four empty carousel trays.

7. Overhead projector.

8. Chalk, felt-tip markers, erasers, etc.

9. Six to eight chairs randomly spaced at back and sides of room for visitors.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Troubleshooting and Laboratory Practices (10 minutes)	Use Slide 179.2/7.1.1 Slide 179.2/7.1.1 is a blank.
A. The Process of Troubleshooting	Key Point: Use of the Process of Troubleshooting requires good lab results in many cases.
1. Use of a systematic troubleshooting system may be dependent on good lab capabilities, especially with larger, more complex plants.	
2. As you recall, one of the main steps in the Troubleshooting Process is "Analyze and Learn". Because of this, the lab is very significant in determining data.	Relate Process of Troubleshooting to lab analyses. Refer class to the Process of Troubleshooting, *Trainee Notebook*, page T2.2.8.
3. Use Slide 179.2/7.1.2 and point out steps where lab is used in troubleshooting.	Use Slide 179.2/7.1.2 Slide 179.2/7.1.2 is a word slide which reads: "Using the Lab in the Process of Troubleshooting Step 1e - Sample, Test and Analyze Step 1f - Process Test and Analyze Step 4 - Observe and Test Step 5b - Monitor Results"
4. Ask students to list the ways that they have had lab experience (i.e., sample collection, performing tests, using lab data for decision-making).	Use answers to key discussion throughout session.
B. Process Controls	Key Point: As pointed out earlier, inadequate labs have been found to be a major reason for inadequate process controls.
1. 1975 survey of federally funded wastewater treatment facilities showed:	
a. 20% of all secondary treatment plants are "marginal", meaning they can meet secondary treatment requirements with improved O & M.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. In many plants, process controls are lacking because of inadequate operational data (primarily smaller plants).	Refer trainees to papers by Hegg and Gilbert, listed in References, *Trainee Notebook*, page T1.3.5.
c. Inadequate operational data most frequently results from: 1) Inadequate lab facilities, 2) Inadequate sampling and testing programs.	
2. Most process control guides and methods depend upon lab test results. These are detailed under the various process operational control sessions.	
3. Process control lab guides have been developed. Examples:	
a. Al West - *Operational Control Procedures for the Activated Sludge Process, Part II, Control Tests*, NTOTC. b. Hayes & Zickefoose - *Operator's Pocket Guide to Activated Sludge, Part II, Process Control and Troubleshooting*. c. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*.	These guides are used in the course as texts and are included in the trainee materials distributed to trainees. Other guides are listed in the References, *Trainee Notebook*, pageT7.3.1.
C. Uses of the Laboratory	
1. The laboratory can be the "best friend" of the troubleshooter and plant operator.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Plant operators and troubleshooters must know how to use the lab so that it gives the information they need.	
3. Lab users should evaluate the lab to see if it is performing up to standards (can it's lab results be trusted??).	
4. The operator and the troubleshooter must be able to distinguish between the various uses of the lab.	
a. Use Slide 179.2/7.1.3 and discuss purposes for obtaining laboratory data.	Use Slide 179.2/7.1.3 Slide 179.2/7.1.3 is a word slide which reads: "Reasons for Using Plant Lab Performance Compliance Records Historical Interest Process Control To Design Plant Improvements Cost Data Comparisons Troubleshooting Operational Problems"
b. Use Slide 179.2/7.1.4 to compare and contrast "record" vs. "process control" testing. Emphasize point "b" under each test purpose.	Use Slide 179.2/7.1.4 Slide 179.2/7.1.4 is a word slide which reads "Record VS Control Testing 1. Record: a. To Monitor Past Performance b. Officially Recognized Methods c. Acceptable Long-Term Records 2. Control: a. To Upgrade Present Performance b. Rapid Tests of Status Now for Corrective Action c. Short Term Interest"

LESSON OUTLINE

c. Use Slide 179.2/7.1.5 to illustrate process control tests which do not have to be run in conformance with "Standard Methods" procedures. However, such tests must be performed using a consistent procedure.

5. Points to stress:

   a. "Standard Methods" procedures are required for NPDES reporting, but

   b. For process control testing and troubleshooting, may use other tests which:

      1) Reflect process conditions and performance.

      2) Can be performed quickly and easily.

      3) Can be performed by shift operators.

      4) Give reasonable accuracy. However, extreme accuracy is not needed as long as trends can measured and consistent results can be obtained. Precision is more important than accuracy so that results can be related to process conditions and performance.

   c. Necessary equipment should be provided to operators for process control tests as well as NPDES required tests.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/7.1.5

Slide 179.2/7.1.5 is a word slide which reads:

"Process Control Information

Look-Feel-Smell
Temperature
Blanket Depth
Settling Rate
Conductivity
Turbidity
D.O.
Flow"

Note: Even a limited lab program can have some quality control:

1. Standardize field method against reference standard of known value.
2. Evaluate against plant performance.

LESSON OUTLINE

Often it is not. Why not??

1) May be oversight - due to lack of operational control expertise on part of engineers.

2) Reluctance on part of some EPA reviewers to fund non-NPDES equipment.

II. Guide to Sampling (20 minutes)

A. Sampling for Troubleshooting (5 minutes)

1. To assist the operator and collect samples for investigation, the troubleshooter needs to know routine sampling requirements.

2. Troubleshooters should be familiar with available guides to lab procedures.

a. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, (EPA).

b. *Operations Manual for Aerobic Biological Wastewater Treatment Facilities*, (EPA)

c. *Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities*.

d. *Operations Manual for Anaerobic Sludge Digestion*.

e. *Operations Manual for Sludge Handling and Conditioning*.

f. *Operations Manual for Stabilization Ponds*.

KEY POINTS & INSTRUCTOR GUIDE

Have class discuss this frequent error in specifying laboratory for treatment facilities.

Complete references to all manuals are included in the units of instruction dealing with each process. References are listed in the *Trainee Notebook* by process.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. Troubleshooters should try to isolate plant problems by analyzing records and trends from process testing for the entire plant and then narrow the testing down to the actual problem areas.	Note: Data should be collected for at least 30 days prior to the problem.
4. Have plant lab personnel, if there are any, run process tests for specific processes in trouble to analyse specific alternative courses of action.	
5. Use Slide 179.2/7.1.6 to summarize this section.	Use Slide 179.2/7.1.6 Slide 179.2/7.1.6 is a word slide which reads: "Sampling for Troubleshooting Be Familiar with Routine Sampling for Process Controls Use EPA Manuals for Reference Isolate Problems By Analyzing Plant Records and Trends Run Process Tests in Plant Problem Areas"
B. Sampling Procedures and Sample Handling (10 minutes)	
1. Troubleshooter must know proper sampling procedures in order to:	Key Point: Troubleshooters must know sampling procedures.
a. Evaluate plant personnel performance in this area.	
b. Recommend improvements to plant superintendent regarding sampling and laboratory techniques.	
c. Supervise plant personnel at process testing.	
d. Sample him/herself where necessary to troubleshoot operating problems.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Sample Types	
a. Use Slide 179.2/7.1.7 to define grab, composite and flow proportional composite samples	Use Slide 179.2/7.1.7 Slide 179.2/7.1.7 is a word slide which reads:
b. Have class discuss each sample type in relation to plant troubleshooting with emphasis on when, where and how each would be used by the operator and the troubleshooter.	"Sample Types Grab Sample - manually collected at a single location and time Composite Sample - combines two or more grab samples Flow Proportional Composite Sample - Grab specimens are in proportion to flow - most reliable"
c. Grab Sample	Guide: More detailed explanation of material on slide.
1) A grab sample is manually collected at a single location and moment in time. Information gained from the grab sample is truly representative of the stream sampled for only that moment in time.	
2) Individual testings of repetitive grab samples collected at frequent intervals over an extended period of time will yield valuable information concerning the variations and degree of variations of the water or waste chemical characteristics.	
3) Grab samples are ordinarily specified where the parameter to be analyzed is unstable and subject ot rapid change (e.g., pH, bacteria, acidity).	

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

d. Composite Sample

A composite sample may be obtained by combining two or more grab samples into a single specimen for analysis. Data derived from analysis of a composite sample is indicative of the average stream character. The reliability of the composite sample as an indicator of average character is increased in proportion to the increasing number of grab samples used in preparing the composite.

e. Flow Proportional Composite Sample

A composite sample obtained by combination of grab specimens in proportion to flow at time of individual grab specimen collection is known as a flow proportioned composite. Flow proportioned composite samples yield the most reliable data concerning average chemical characteristics over the sampling interval.

The formula commonly used for flow proportional composite samples may be written on the blackboard:

ml of individual sample required in composite =

$$\frac{\text{flow rate at sampling time}}{\text{average flow rate}} \times \frac{\text{total sample size}}{\text{number of sampling times}}$$

3. Sampling Frequency and Location

a. NPDES Permit Monitoring

The NPDES permit for the wastewater treatment facility under evaluation will specify the location and frequency of sampling for applicable NPDES test parameters.

The troubleshooter should assure that sampling personnel understand designated sampling frequency and location and are satisfying these permit conditions.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. Process Control Sampling 1) Process control sampling frequency and location is dependent upon plant size, types, degree of treatment provided, type and nature of industrial wastes received and historic as well as existing plant performance. 2. The troubleshooter may wish to perform an estimation of minimum and optimum sampling/testing needs for a particilar plant prerequisite to his/her visitation by comparison with the estimated required program.	Note: Most operations guides list minimum process control sampling schedules. EPA manuals, in particular, tend to recommend sampling schedules more suited to effluent monitoring needs than to process control needs. The troubleshooter must recommend a sampling schedule that gives adequate information for process control decision making. Troubleshooters must be aware that excess laboratory testing may unnecessarily divert resources from other operations and maintenance tasks.
4. Sampling Technique and Equipment a. Sampling should be performed in a manner which yields truly representative specimens free of perturbations and/or contaminating materials which may lead to erroneous conclusions. For example, effluent samples should not contain leaves or other floating materials, sediment scoured from channel bottom during sampling, etc...which would influence test results and present a misleading characterization of the effluent quality.	Use Slide 179.2/7.1.8 Slide 179.2/7.1.8 is a word slide which reads: "Sampling Technique and Equipment Samples Must Be Representative Sufficient Volume for Lab Testing Clean Bottles and Apparatus Proper Labeling and Identification Automatic Devices Must Be Inspected Samples Taken to Lab Without Delay Sterile Bottles for Bacterial Testing"
b. Samples must be of sufficient volume to enable proper laboratory processing and testing.	Guide: Required Sample testing volumes are listed with the test procedure descriptions.
c. Sample collection apparatus and sample bottles should be clean to prevent contamination and possible test interferences. Plastic and glass containers are preferred to metal.	

LESSON OUTLINE

KEY POINTS &
INSTRUCTOR GUIDE

d. Samples should be labeled properly to facilitate chemist's identification of sample location, collection time, date and sampler.

e. Automatic sampling devices should be inspected periodically to assure timer controls, refrigerator unit or other critical components are in proper working order and that they are clean!

f. Sample should be taken to the laboratory without unnecessary delay.

g. Samples for bacteriological testing should be collected manually using sterile bottles and aspetic technique. Samples should be obtained from at least 6 inches below the water surface. The bottle should not be filled to the top to enable proper mixing prior to testing.

5. Preservation of Samples

   a. Specific preservation techniques are given in *Standard Methods for the Examination of Water and Wastewater.*

Refer trainees to applicable texts prior to initiating a laboratory or plant investigation.

   b. General considerations:

      1) Samples must be preserved to make certain that their characteristics do not change in quality or quantity.

      2) Return all samples to lab as soon as possible.

      3) Unstable tests (D.O., pH, etc.) must be tested on-site.

LESSON OUTLINE

4)

Preservative	Used For
$HgCl_2$	Nitrogen forms Phosphorus forms
Nitric Acid	Metals
Sulfuric Acid	Organic samples
NaOH	Cyanides Organic acids
Refrigerate @ 4°C	Acidity, Alkalinity, Organics, BOD, Biological organisms, Color etc.

C. Discussion (5 minutes)

1. Have class cite examples from their experience to illustrate how sample collection or preservation techniques have affected results.
2. Have class discuss the question: "What is an adequate laboratory testing program for the small plant as compared to the large plant?"
3. Have class discuss the advantages and disadvantages of using contractual laboratory services rather than performing all laboratory functions inhouse.
4. Have class discuss the question, "Who should make process control decisions, the operators or the laboratory staff?"

KEY POINTS & INSTRUCTOR GUIDE

May write these on blackboard if desired. See if there is interest in the details of preserving samples.

Use Slide 179.2/7.1.9
Slide 179.2/7.1.9 is a blank.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 7: Laboratory Practices

Lesson 2: Troubleshooting Laboratory Practices

Lesson 2 of 3 lessons Recommended Time: 60 minutes

Purpose: One of the most frequently cited causes for poor wastewater treatment facility performance is inadequate laboratory testing and failure to use laboratory test results in process control decision making. This lesson stresses the importance of evaluating the laboratory and the laboratory testing program as an integral component in troubleshooting wastewater treatment facilities.

Trainee Entry Level Behavior: Trainees should have completed Unit 7, Lesson 1 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. List and evaluate the main factors which indicate laboratory adequacy.
2. Discuss main considerations in evaluating staff composition and procedures.
3. Outline methods of evaluating laboratory facilities and equipment.
4. Outline method of evaluating laboratory test results.
5. Identify laboratory safety hazards.
6. Describe the limitations to troubleshooting laboratory problems and approach troubleshooting with a systematic approach.

Instructional Approach: Illustrated lecture.

Lesson Schedule: The 60 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 5 minutes	Indicators of Laboratory Adequacy
5 - 20 minutes	Troubleshooting Staff Deficiencies and Procedures
20 - 50 minutes	Troubleshooting Laboratory Facilities and Equipment
50 - 60 minutes	Troubleshooting Laboratory Problems

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, page T2.2.8, "Process of Troubleshooting."

2. *Trainee Notebook*, page T7.2.1, "Major Steps in Troubleshooting a Laboratory Program."

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 7.2.1 - 7.2.20, Unit 7, Lesson 2.

2. Slides 179.2/7.2.1 - 179.2/7.2.29.

Instructor Materials Recommended for Development: None

Additional Instructor References: As specified for Unit 7, Lesson 1.

Classroom Set-Up: As specified for Unit 7, Lesson 1.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Indicators of Laboratory Adequacy (5 minutes)	Use Slide 179.2/7.2.1 Slide 179.2/7.2.1 is a blank. Refer class to page T7.2.1 in *Trainee Notebook*.
A. Use Slide 179.2/7.2.2 to briefly review the three principal factors which the troubleshooter can use to evaluate the lab's adequacy.	Use Slide 179.2/7.2.2 Slide 179.2/7.2.2 is a word slide which reads: "Evaluating Laboratory Adequacy Principal Factors Staff Composition and Procedures Physical Facilities and Equipment Laboratory Test Results"
B. Evaluating Laboratory Staff Composition and Procedures 1. A well-trained staff = better operations. 2. Evaluate the number and training of staff. a. Use EPA guide *Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities* as a starting point. b. Does staff size seem adequate for existing needs? Are there firmly based complaints that the staff size is too small? c. Is there an in-house training program? Were trained analysts hired for labs? Are the people concerned about good lab operations? 3. Examine the handling of samples, data and equipment.	Use Slide 179.2/7.2.3 Slide 179.2/7.2.3 is a word slide which reads: "Evaluating Laboratory Staff Composition and Procedures Number and Training of Staff Handling of Samples, Data and Equipment Existance of Quality Control Procedures Ability to Perform NPDES Testing Procedures for Process Control Testing Assistance Provided to Troubleshooters"

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

a. Even if you are not a trained analyst, much of this will be common sense!

b. Do they seem to follow standard recommended procedures?

c. Is there good record control (do they "loose" samples or test results)? Do they seem aware of housekeeping and equipment needs as outlined in the lab O & M manuals?

d. Much of this will become obvious as you talk with personnel - not only lab managers - also analysts and sample collectors.

Guide: Often, lab problems are due to misinformation and/or communication problems within the various staff functions.

4. Look at the existence of quality concontrol procedures and the ability to perform NPDES testing.

   a. Good lab results will tell you what the treatment plant is doing - poor lab results are worse than no lab results.

   b. For this reason, the use of quality control and an ability to get good lab results are very important! More time will be spent on these topics.

5. Check that there are procedures for process control testing.

   a. For day-to-day operations, these are critical and should not be ignored.

   b. Make certain that process control test results are checked against plant performance and that records are kept to show trends.

Note: In some cases, it makes more sense for plants to "farm out" NPDES testing and spend their time perming complete process control checks.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
5. Is there a willingness to provide assistance to the troubleshooters? a. Are they eager to share lab information? b. Do they withhold data? Act suspicious? Alter data? c. Can they do what you ask them to do?	Note: Troubleshooters who have extensive laboratory experience are better equipped to evaluate the laboratory functions than are troubleshooters with limited lab experience.
B. Evaluating Laboratory Facilities and Equipment 1. Use Slide 179.2/7.2.4 to highlight points to be covered in this section. Note that much of this can be done using a common sense approach. Use the slide to list the main points which will be covered in the following discussion.	Use Slide 179.2/7.2.4 Slide 179.2/7.2.4 is a word slide which reads: "Evaluating Laboratory Facilities and Equipment Adequacy of Equipment and Facilities for the Job to be Done Cleanliness and Overall Housekeeping Maintenance of Equipment and Facilities Degree of Down-Time Attention to Safety Hazards and Safety Precautions"
2. Adequacy of equipment and facilities for the job to be done a. Have class critique Slide 179.2/7.2.5. b. This may be a problem that the operator can do little about. c. Check that major equipment items have been provided and that there is adequate space in which to work.	Use Slide 179.2/7.4.5 Slide 179.2/7.4.5 is a photograph showing a very cluttered laboratory facility adjacent to maintenance work areas.
d. If facilities are inadequate, look at replacement facilities.	Note: Replacement facilities may be found inexpensively if time and effort are put into the search. For example, the municipality may have access to additional buildings, the local school may allow use of their lab space, etc.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. Cleanliness and overall housekeeping	Use Slide 179.2/7.2.6
a. Have class critique Slide 179.2/7.2.6.	Slide 179.2/7.2.6 is a photograph showing a laboratory titration area which has not been cleaned. Spilled chemicals, reagent bottles and dirty glassware are visible throughout the slide.
b. Poor housekeeping may signal an overall lack of interest in lab operations.	Note: This may also signal difficulties with facilities plan, personnel or equipment.
c. Test results often in question in a poor cleanliness situation.	
4. Maintenance of equipment and facilities	Use Slide 179.2/7.2.7
a. Are lab analysts aware of equipment O & M needs. Locate reference manuals if possible.	Slide 179.2/7.2.7 is a photograph which shows laboratory equipment crowded into a small available area.
b. Do they appear to take care of equipment? Units are kept clean, covered when not in use, etc.	
c. Are facilities being used in an approved way?	
5. Degree of down-time	Use Slide 179.2/7.2.8
a. Improper equipment and facilities maintenance will result in costly down-time.	Slide 179.2/7.2.8 is a photograph of a pH meter that is sitting in the maintenance area showing various burners, pipe fittings, etc., etc.
b. The occurrence of a lot of equipment down-time may signal poor equipment O & M, which may in turn signal poor lab test procedures and incorrect data.	Note: There are occasions when equipment down-time is due to inadequacies of lab equipment design.
6. Attention to safety hazards and safety precautions	
a. Safety hazards should always be a major concern to lab personnel.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
b. You, as a troubleshooter, have a responsibility to point out obvious health and safety hazards.	
c. Examples:	
Improper Storage of Acids/Alkalis 1) Note sink and drain need repairs 2) Note corrosion of floors.	Use Slide 179.2/7.2.9 Slide 179.2/7.2.9 is a photograph showing improperly stored acids and bases, Cleaning supplies, insect repellents and other miscellaneous items are stored with these hazardous chemicals.
Overloaded Electrical Outlets 1) A real fire hazard!	Use Slide 179.2/7.2.10 Slide 179.2/7.2.10 is a photograph showing an overloaded electrical outlet and adjacent to a gasline - an obvious fire hazard.
Poor Pipetting Technique 1) Note concentrated sulfuric acid being mouth-pipetted. 2) Where is worker's protective clothing? 3) What would you guess is the skill level of this worker?	Use Slide 179.2/7.2.11 Slide 179.2/7.2.11 is a photograph showing a laboratory technician mouth pipetting from an acid bottle. The technician is not wearing protective clothing.
C. Evaluating Laboratory Test Results 1. Until you are familiar with actual lab test procedures, you can begin to evaluate lab test results by items listed on Slide 179.2/7.2.12. 2. Once you become more familiar with the required test procedures, you can look at troubleshooting staff deficiencies and laboratory procedures.	Use Slide 179.2/7.2.12 Slide 179.2/7.2.12 is a word slide which reads: "Evaluating Laboratory Test Results Incomplete Data and Records Inconsistent Results Signs of Inaccuracy Evidence of Quality Controls Absent 'Dry Labbing'- Pencil Chemists"
II. Troubleshooting Staff Deficiencies and Procedures (15 minutes)	Use Slide 179.2/7.2.13 Slide 179.2/7.2.13 is a word slide which reads:

LESSON OUTLINE

A. Evaluating Operating Procedures

Any of the factors listed on the slide could be responsible for faulty and invalid laboratory results.

1. Sampling Technique
    - a. Discussed in Lesson 1.
    - b. References should be used if questions arise.
    - c. If troubleshooter observes or suspects invalid sampling, he/she should work with chemist and plant operator in advising how to upgrade.
2. Use of Approved Test Procedures
    - a. Make sure chemist and operator are aware of proper testing procedures.
    - b. Lab adequacy is a factor. Valid tests cannot be run using inadequate equipment.
    - c. Prescribed tests must be run.
        - 1) *Federal Register* prescribed tests for NPDES.
        - 2) *Standard Methods* where applicable
        - 3) Consistent and valid process control tests, even when "quick and dirty" methods are used.
    - d. Testing can be upgraded by:
        - 1) Lab staff training.
        - 2) Developing systematic testing program.
        - 3) Some outside contracting, if lab is inadequate or staff is overworked or incapable.

KEY POINTS & INSTRUCTOR GUIDES

"Evaluating Operating Procedures

Sampling Technique
Approved Test Procedures
Quality Control
Record Keeping and Reporting"

LESSON OUTLINE

e. Test kits have serious shortcomings

   1) Useful for field operations, some stream sampling.

   2) Invalid for NPDES and process control testing.

   3) Used in many low budget labs.

   4) Some pre-packaged kit tests have been approved for NPDES. Check with EPA regional laboratory personnel for a listing of those which have been approved.

   5) Frequently adequate for process control.

f. Be aware of potential areas of error for approved test procedures.

   1) Organic tests - contamination

   2) Oxygen Demand Tests - contamination

   3) B.O.D. - nitrifying organisms

   4) Solids tests - weighing techniques

   5) Instrumentation - equipment problems

3. Quality Control and Validation

   a. Quality control can be used for small plants as well as larger plants.

   b. Quality control for NPDES tests will be detailed by EPA according to *Standard Methods* procedures.

   c. Quality control for process control tests is as important as quality control for NPDES testing.

KEY POINTS & INSTRUCTOR GUIDES

Key Point: Problems with test kits include: accuracy, consistency and conformity with accepted test results.

Key Point: Make certain that you, as the troubleshooter, are aware of the most current quality control requirements before you try to troubleshoot a laboratory test procedure.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
d. Lab chemist should establish quality control program to	
1) Monitor reliability of reported data.	
2) Meet program requirements for reliability.	
e. Troubleshooter's role	Note: Again stress the indirect role of the troubleshooter.
1) Should determine if quality control program exists.	
2) Should recommend use of:	
a) Split samples	
b) U.S. EPA reference standards	Guide: Contact your regional U.S. EPA office (quality assurance branch) to obtain information on obtaining reference standards for quality control.
c) Commercial reference standards	
3) Should refer problems to qualified experts.	
4. Record Keeping and Reporting	
a. Forms and bench sheets	
1) Should be standardized and designed to fit the needs of the lab.	
2) Should be maintained according to NPDES required 3-year interval.	
3) Data should be transposed to a more permanent log.	
b. NPDES Reporting	
1) Should observe criteria specified in permit.	
2) Plant evaluator and troubleshooter should inspect file to see if reports are being properly completed	

c. Storage and retrieval of data

1) Easily located permanent log should be used.

2) Log should be permanently bound.

3) Log should be validated by plant chemist after data is transposed.

B. Evaluating Adequacy of Lab Staff (5 minutes)

1. Staffing needs can be estimated by using nomograph found in EPA manual *Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities*.

   a. The staffing guidelines were developed from information collected at wastewater treatment plants throughout the country. The guidelines do not reflect what may need to be recommended.

   b. The troubleshooter may use the EPA Lab Guidelines to confirm suspected staff inadequacy, but the troubleshooter is urged to also investigate the staff needs in more depth.

2. Personnel Qualifications

   a. A well-trained staff lends itself to more efficient operation in the laboratory. Certification of lab workers is a method of evaluating personnel capabilities.

   b. In most cases, the troubleshooter will not be capable of judging the personnel qualifications.

3. Upgrading staff adequacy

In most instances the troubleshooter's role is necessarily limited to explaining the problem of staff inadequacy to the appropriate municipal officers. The troubleshooter may, however, be able to

Key Point: Troubleshooter's play an indirect role in upgrading plant laboratories.

LESSON OUTLINE

recommend one or more options available for resolving the problem.

III. Troubleshooting Laboratory Facilities and Equipment (30 minutes)

A. Equipment (5 minutes)

1. Troubleshooter need not be an expert on laboratory equipment, but should know

   a. Basic equipment needs

   b. When equipment is properly mounted, installed and maintained.

2. Basic reference on equipment - Chapter III of EPA manual *Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities* - Appendix B.

3. Basic equipment and troubleshooting signs

   The simplest reasons for equipment breakage and poor operation are cleanliness and maintenance. If you find yourself dealing with more complicated equipment items, refer to the unit's O & M manual before attempting to troubleshoot it.

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/7.2.14
Slide 179.2/7.2.14 is a word slide which reads:

"Options for Upgrading Lab Staff

Increase Staff Number
Rearrange Sampling/Testing Duties
Eliminate or Reduce Unnecessary Testing
Increase Supervision by Qualified Staff
Upgrade Equipment to Reduce Testing Times
Formal or On-Site Training
Sub-Contract Difficult Tests"

Use Slide 179.2/7.2.15
Slide 179.2/7.2.15 is a blank.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDES

B. Physical Facilities (3 minutes)

1. Inadequate physical facilities can lead to:
    a. Reduction in lab efficiency
    b. Reduction in testing capability
    c. Reduction in staff morale
    d. Higher frequency of laboratory accidents
    e. Excessive breakage of glassware
2. Adequacy evaluated through nomographs presented in EPA manual *Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities*. The manual discusses
    a. Floor space requirements
    b. Bench area requirements
    c. Storage cabinet requirements

C. Necessary Chemicals and Supplies (2 minutes)

1. The troubleshooter will have little reason to review laboratory stock of chemicals and miscellaneous supply items. However, should inefficient laboratory work appear to be due to inadequate supply of chemicals, he/she may wish to take a closer look at chemical reagent stock and inventory practices.
2. Many of the problems associated with chemicals and supplies are due to
    a. Deterioration of chemicals - poor storage and conditions.
    b. Incorrect preparation of chemical solutions
    c. Invalid/outdated test kit reagents

Note: The troubleshooter should make certain to have an understanding of chemical solutions before attempting to troubleshoot specific chemical solution problems.

d. Old chemical solutions - compare expiration dates against those listed in test procedures.

3. Listing of needed chemicals may be found in the EPA manual *Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities*.

D. Laboratory Maintenance and Housekeeping (10 minutes)

Perhaps the best indication of probable inefficient laboratory operations and/or poor data quality is the appearance of the laboratory surroundings. A dirty or cluttered laboratory may reflect an improper attitude of the staff toward their testing responsibilities and similar lack of concern for good analytical technique.

1. Good laboratory housekeeping minimizes common lab accidents, reduces risk of sample contamination, improves the efficiency of the staff and creates a pleasant environment leading to better staff morale.

   a. Floors and aisles are clear of obstructions and clean.

      Spillages of chemicals and water are promptly attended to in order to prevent accidents.

   b. Windows and lighting fixtures are clean in order to facilitate reading of analytical glassware and meters.

   c. Dirty glassware is washed as frequently as necessary to provide readily available stock for testing demands.

   d. The troubleshooter should recommend improved housekeeping in the laboratory should he/she feel it will benefit the operation.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
2. Laboratory maintenance should include periodic inspection of exhaust system, water, gas and electrical service, lighting and drains	
a. Failure of laboratory drain systems due to chemical attack may require substantial time for repair. Unless scheduled, such failures and repairs may affect prolonged periods of laboratory down-time.	
b. Periodic inspection of laboratory wiring systems may prevent serious damage to the lab facility. The inherent nature of the chemicals found in the laboratory dictate all possible fire hazards should be monitored and corrected as indicated.	
3. Visual observations are valuable in determining the quality of laboratory maintenance and management.	Guide: Use the following picture slide series to show the "do's" and "don't" of laboratory housekeeping. Slides should be shown in rapid sequence. Class should be asked to comment and to point out problems portrayed by slides. Instructor should use this slide series as an opportunity for trainee involvement in the lesson.
Show the following slides:	Guide: Seek comment from class on these slides.
a. Slides illustrating poor lab facilities	
b. Poor facilities 1) Absorbent, dirty bench top 2) Poor storage practices 3) Floor and walls dirty and cluttered 4) Inadequate sink - dirty glassware?	Use Slide 179.2/7.2.16 Slide 179.2/7.2.16 is a photograph showing a cluttered laboratory sink area which has not been cleaned. Various chemicals, materials and other items are randomly stored beside the sink. Some chemicals are stored on a shelf above the sink.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
c. Poor facilities 1) Inadequate sink and utilities - only cold water? 2) Inadequate lighting 3) Is phosphorous-free soap used for cleaning glassware for phosphorous testing - what will acid do to this sink?	Use Slide 179.2/7.2.17 Slide 179.2/7.2.17 is a photograph showing the laboratory sink that was in the previous slide. The various chemicals that are randomly beside the sink are shown in close up. It is noted that coffee and other food supplies are mixed with the laboratory chemical storage bottles.
d. Poor facilities? 1) Get opinion from class as to what is wrong, if anything.	Use Slide 179.2/7.2.18 Slide 179.2/7.2.18 is a photograph showing a reflux condenser set-up for COD analysis. The equipment area is somewhat crowded, but all-in-all, reflects a clean laboratory work area that makes maximum use of available space.
e. Good facilities Adequate floor space and bench space good maintenance.	Use Slide 179.2/7.2.19 Slide 179.2/7.2.19 is a photograph of a small wastewater treatment laboratory which is in good, clean order. The slide illustrates effective use of limited laboratory space.
f. Good facilities with lab desk area. Equipment neatly arranged.	Use Slide 179.2/7.2.20 Slide 179.2/7.2.20 is a photograph of the laboratory showing adequate laboratory space with sufficient area for chemist and technicians.
g. Balance Table and related equipment. Is this table appropriate for the use.	Use Slide 179.2/7.2.21 Slide 179.2/7.2.21 is a photograph showing a balance table with both a mechanical double pan balance and a single pan electronic balance on the table. The layout is good, the balance table is clean and orderly, the laboratory notepad and desiccator are located on the right hand side of the balance.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
h. Poor utilization of bench space 1) Note food preparation 2) Note chemicals next to food materials - poison?	Use Slide 179.2/7.2.22 Slide 179.2/7.2.22 is a photograph showing a coffee pot and food supplies stored in the laboratory area.
i. Good utilization of limited bench space 1) Note consolidation of distillation/reflux activities. 2) General neatness implies concern for testing duties.	Use Slide 179.2/7.2.23 Slide 179.2/7.2.23 is a photograph showing a COD reflux condenser set-up which is well lighted, clean with sufficient space for laboratory technicians to work satisfactorily. Question: Is the proximity to the window a problem?
E. Laboratory Safety (10 minutes) 1. The inherent potential for danger in the laboratory is great, due to use of toxic, volatile, and combustible chemicals, use of open flame and quantity of exposed glassware. Some personal risk is present due to the nature of samples being tested. The troubleshooter should be prepared to note inadequacies in laboratory safety and make appropriate recommendations, although he/she should be aware that the actual authority for safety requirements is with OSHA, U.S. Department of Labor.	
2. Laboratories should be equipped with proper safety equipment, including:	Guide: Use the following slides to discuss lab safety.
a. Fume Hood Best located near area of highest testing activity. Additional exhaust systems may be needed where excessive heat, chemical vapors or noxious fumes are generated. Areas to be hooded are found near autoclaves, furnaces, locations for bacteria testing, etc.	Use Slide 179.2/7.2.24 Slide 179.2/7.2.24 is a photograph of a chemical fume hood showing hazardous chemicals stored inside the hood. Preferred method would be to store them in a hazardous materials cabinet, but lacking such a storage facility, the hood is probably a satisfactory storage area although it would be better to store the chemicals on a lower shelf instead of the upper working surface of the fume hood.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
b. Fire extinguishers of proper type, mounted in convenient locations and in accordance to code, and bearing tags certifying regular service.	Use Slide 179.2/7.2.25 Slide 179.2/7.2.25 is a photograph of a safety shower with eye wash in the laboratory.
c. Eye wash facilities available. May be hand held, economical wall mounted units or fixture type.	Use Slide 179.2/7.2.26 Slide 179.2/7/2/26 is a photograph of an emergency portable eye wash in the laboratory.
d. Emergency shower is available and not used for storage.	Use Slide 179.2/7.2.27 Slide 179.2/7.2.27 is a photograph of a close-up view of an emergency shower and eye wash in the laboratory.
3. Other safety precautions should include:	Key Point: The instructor should relate lab safety to an approach discussed in the lesson on Management Behavior - that of Management Systems. Does the lab (being inspected) have an organized safety program? Is there a management system for safety?
a. Fire blanket available to supplement emergency shower or in lieu of shower.	
b. Laboratory aprons, smocks, coats, rubber and asbestos gloves, eye	
c. First aid station available at convenient location in laboratory.	
d. Facilities for quick mop-up of chemical spills are available (e.g., sand-soda ash buckets, etc.).	
e. Shields available and used in front of distillation glassware.	
4. Some laboratory safety hazards for troubleshooter to be aware of:	
a. Poor storage and use of shelf	Use Slide 179.2/7.2.28 Slide 179.2/7.2.28 is a photograph showing chemicals and dilution water stored on a shelf above the lab work bench area.
1) Note shelf has no restraining lip.	
2) Note acid bottles (glass) and heavy water carboys on poorly fabricated/supported shelf.	
3) Acids should be stored at floor level for safety.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
End of Slide Series	Use Slide 179.2/7.2.29 Slide 179.2/7.2.29 is a blank.

Note that slides were taken at laboratory of treatment plant at Perrysburg, Ohio, which is a 2.74 MGD activated sludge plant serving 8,000 people in northwest Ohio. This plant is unusual in that the superintendent is a skilled laboratory chemist and operator, and for several years ran a commerical analytical laboratory. The slides showing good conditions were actual, whereas the slides showing poor conditions were staged.

IV. Troubleshooting Laboratory Problems (10 minutes)

A. Laboratory Test Results

It is possible that treatment process performance and overall plant efficiency are lower than design levels because the laboratory is providing inaccurate or misleading test data.

1. While possible, this is unlikely because plants which are well enough run to rely on lab tests for process controls are likely to have adequate laboratories.

2. If lab test results are suspect, parallel tests using outside laboratories should be run in order to validate lab results.

3. Troubleshooters can look for the following indicators of possible deficient lab results:

Key Point: Keen observations are an important part of the Process of Troubleshooting.

   a. Incomplete data and records.

   b. Inconsistent results.

   c. Signs of inaccuracy - poor lab equipment use and procedures, etc.

   d. Evidence of quality controls.

   e. "Dry labbing."

4. Generally, lab results will be good if the lab:

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
a. Is adequately staffed with properly trained personnel.	
b. Utilizes standard and consistent procedures.	
c. Has adequate bench and floor space.	
d. Utilizes basic laboratory equipment, properly maintained.	
e. Shows evidence of good housekeeping and maintenance.	
B. Barriers for Troubleshooters to Overcome in Upgrading Laboratory Adequacy	Guide: Stress importance of troubleshooter attitude and behavior in helping plant superintendents solve problems.
1. It's easier to isolate problems than to recommend workable solutions.	
2. Troubleshooter cannot enforce corrective action, he/she must be a convincing "salesperson."	
3. Must be able to document problems and justify recommendations.	
4. Must present alternatives where possible and stress possible benefits to municipality.	Stress the Systematic Process of Troubleshooting.
5. Troubleshooter may expect to encounter the following attitude barriers:	
a. Administration reluctant to appropriate funds for upgrading lab operations - a budget account historically regarded as nonessential to the treatment plant operation.	
b. Resentment of lab staff to implication of technical inadequate or incompetence	
c. Reluctance of plant operators to assume new or additional sample collection or testing responsibilities often regarded by them as "part of the chemist's job."	
C. Questions and Answers	Use remaining time for discussion

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 7: Laboratory Practices

Lesson 2: Troubleshooting Laboratory Practices

Trainee Notebook Contents

Major Steps in Troubleshooting a Laboratory Program T7.2.1

568

Major Steps in
Troubleshooting a Laboratory Program

1. Decide what tests need to be run and their frequency.
    a. NPDES Monitoring
    b. Plant Process Control
    c. Historical Data Collection on Plant and Unit Performance
    d. Troubleshooting
    e. Other

2. Evaluate existing physical facilities and equipment.

3. Evaluate staff composition and training

4. Evaluate laboratory testing procedures.
    a. Sample Collection, Handling and Preservation
    b. Test Method Used and Modifications
    c. Parameter Problem Areas
        1) Oxygen Demand Tests
        2) Residue Determinations
        3) Nutrients Tests
        4) Metals Tests
        5) pH
        6) Biological Tests (bacterial usually)
        7) Others
    d. Laboratory Safety
    e. Quality Control
    f. Records

5. Evaluate the laboratory test results
    a. Inter- and Intra-Laboratory Analysis
    b. Use of Reference Standards

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 7: Laboratory Practices

Lesson 3: Laboratory Equipment

Lesson 3 of 3 lessons   Recommended Time: 30 minutes

Purpose: Review common wastewater laboratory equipment and highlight defects which can be spotted during a visual inspection of the laboratory area.

Trainee Entry Level Behavior: Trainee should have completed Unit of Instruction 7, Lesson 2, before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson the trainee will be able to:

1. Visually inspect a wastewater treatment plant laboratory.
2. Recognize poor or improper equipment and/or conditions which may be encountered in a wastewater treatment plant laboratory.

Instructional Approach: Illustrated lecture with trainee discussion.

Lesson Schedule: The 30 minutes allocated to this lesson should be paced by devoting approximately one minute to each slide.

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, page T7.3.1, "References".

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 7.3.1 - 7.3.6, Unit 7, Lesson 3.
2. Slides 179.2/7.3.1 - 179.2/7.3.26.

Instructor Materials Recommended for Development: None

Additional Instructor References: None

Classroom Set-Up: As specified for Unit 7, Lesson 1.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
I. Optional Section on Laboratory Equipment (30 minutes) (See Unit Overview - Presentation Options for Course Director)	Use Slide 179.2/7.3.1 Slide 179.2/7.3.1 is a blank.
A. Objectives of Optional Section 1. To familiarize trainees with commonly used equipment in wastewater treatment plant laboratories. 2. To show favorable and unfavorable conditions for the use of lab equipment. 3. To allow trainees to participate fully.	Guide: If this slide series is used, ample opportunity for trainee discussion and involvement should be provided. Important: Unless discussion is strongly encouraged, trainees may lose interest in the multitude of slides shown. The instructor may shorten this section as he/she sees fit.
B. Slide Key	
1. Analytical Balance (mechanical model) a. Poorly located, no knee space. b. Balance doors left open. c. Weights left on pan. d. Apparent lack of regard for precision instrument.	Use Slide 179.2/7.3.2 Slide 179.2/7.3.2 is a photograph showing a double pan mechanical balance. The weights are still sitting on the pan of the balance. To the right of the balance is an overloaded electrical outlet.
2. Analytical Balance (electrical model) a. Properly located, clean. b. Related equipment nearby (e.g., desiccator).	Use Slide 179.2/7.3.3 Slide 179.2/7.3.3 is a photograph of a single pan electronic balance with desiccator on the right. This looks like a satisfactory installation.
3. Trip Balance a. Technician weighing directly on pan could result in corrosion.	Use Slide 179.2/7.3.4 Slide 179.2/7.3.4 is a photograph showing the laboratory technician weighing chemicals on a double pan trip balance. The lab work space is crowded and the technician is weighing a sample directly on the balance pan.
4. pH Meter a. Preferred condition.	Use Slide 179.2/7.3.5 Slide 179.2/7.3.5 is a photograph showing a pH Meter with adequate and proper storage of buffers, electrodes, etc.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
5. What would signal the improper operation of a pH meter? pH electrodes? pH solutions?	Use Slide 179.2/7.3.6 Slide 179.2/7.3.6 is a photograph showing a pH meter which appears to be non-functional with improperly stored electrodes. Various non-related materials surround the pH meter. This would be an indicator that the pH meter may not be adequately maintained or calibrated.
6. pH Meter a. Meter appears to be satisfactory b. Buffer solutions in open beaker and appear to be contaminated with algae growth.	Use Slide 179.2/7.3.7 Slide 179.2/7.3.7 is a photograph showing a pH meter which is properly maintained but the open buffer with algae growth makes one suspect otherwise.
7. Drying Oven a. Top used for storage of broken glassware - danger! b. Volatile chemicals stored on oven top? c. Top-mouthed thermometer not visible.	Use Slide 179.2/7.3.8 Slide 179.2/7.3.8 is a photograph showing a laboratory oven with the door partially open and chemicals being stored on top of the lab oven.
8. Dry Oven Interior a. Contents in oven located to prevent contamination in event of spillages? b. Crucible and glassware appear to be properly marked to prevent mixup of specimens.	Use Slide 179.2/7.3.9 Slide 179.2/7.3.9 is a photograph of a laboratory oven open. The shelves are overcrowded, but orderly with beakers, crucibles, etc. located to avoid contamination in case of a spillage. There is a trip beam balance sitting on top of the oven.
9. Electric Muffle Furnace a. No exhaust system.	Use Slide 179.2/7.3.10 Slide 179.2/7.3.10 is a photograph of a muffle furnace. It appears to be in good condition.
10. Desiccator (glass model) a. Lid is broken and not matched to base - poor seal?	Use Slide 179.2/7.3.11 Slide 179.2/7.3.11 is a photograph of a desiccator. The top is cracked and judging by the color of the desiccant, it appears it may not have been replaced recently.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
b. Particles of indicator desiccant material (blue) are mixed with non-indicating type. Blue color shows desiccant is still active.	
11. Desiccator (cabinet model) a. Desiccant material is exhausted (pink color).	Use Slide 179.2/7.3.12 Slide 179.2/7.3.12 is a photograph of a cabinet-type desiccator. Judging by colors in the photo it appears that the desiccant is exhausted. It does appear that the desiccator is being used to store beakers of material. It is unknown if these are liquids or solids.
12. BOD Incubator a. Preferred organization of contents and clean chamber. b. BOD bottles do not have top covers - is water seal still present or has it evaporated.	Use Slide 179.2/7.3.13 Slide 179.2/7.3.13 is a photograph of a refrigerator used to store samples and hazardous chemicals. The chemicals stored appears to be well organized and orderly.
13. Water Still (glass model) a. Preferred condition.	Use Slide 179.2/7.3.14 Slide 179.2/7.3.14 is a photograph which shows a glass model water still which appears to be in excellent condition.
15. Water Still (glass model) a. Preferred condition.	Use Slide 179.2/7.3.15 Slide 179.2/7.3.15 is a photograph of another glass water still which appears to be in excellent condition
15. Deionizer System a. Preferred condition - note indicator system built into exchange medium to warn of loss of exchange ability.	Use Slide 179.2/7.4.16 Slide 179.2/7.3.16 is a photograph showing a laboratory deionized water system which appears to be in good condition.
16. Colorimeter a. Preferred condition - note related items nearby. Timer indicated chemist does monitor color development times.	Use Slide 179.2/7.3.17 Slide 179.2/7.3.17 is a photograph of a colorimeter which appears to be in excellent condition. Reagent containers are located adjacent to the colorimeter and appear to be orderly and clean. Timer above

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
	colorimeter indicates that the laboratory technician does monitor color development times.
17. Spectrophotometer a. Preferred condition - note related items nearby including operating instructions.	Use Slide 179.2/7.3.18 Slide 179.2/7.3.18 is a photograph showing a spectrophotometer which is in excellent condition. Note operating instructions for the spectrophotometer posted above and to the right of the unit.
18. Refrigerator a. Poor use of refrigerator - food next to waste specimens. b. What kind of chemicals are stored here? c. Needs defrosting.	Use Slide 179.2/7.3.19 Slide 179.2/7.3.19 is a photograph showing the inside of a refrigerator. Note that food, samples and chemicals are all stored in the refrigerator. The refrigerator needs defrosting.
19. Autoclave a. Preferred condition - note contents wrapped.	Use Slide 179.2/7.3.20 Slide 179.2/7.3.20 is a photograph of an autoclave which appears to be in excellent condition. Note the cloth towel which is being used to cover the specimens to be autoclaved.
20. Electric Hotplates and Heating Mantle (upper right corner) a. Preferred condition b. Note safety goggles near distillation units.	Use Slide 179.2/7.3.21 Slide 179.2/7.3.21 is a photograph showing electrical hotplate and heating mantles. Condition of the units appears to be excellent. The area is clean and orderly. Note the safety goggles that are located adjacent to the unit for use by the technician when refluxing COD samples.
21. Dissolved Oxygen Analyzer a. Preferred condition - related items nearby.	Use Slide 179.2/7.3.22 Slide 179.2/7.3.22 is a photograph of a dissolved oxygen meter showing proper storage of the BOD probe and liquid sample.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
22. Water Bath Incubator a. Lid not properly placed on bath - evaporation? b. Thermometer is missing from bath.	Use Slide 179.2/7.3.23 Slide 179.2/7.3.23 is a photograph of a water bath incubator. Note that the lid on the incubator is not properly placed and that there is no thermometer in the water bath.
23. Total Organic Carbon Analyzer a. Preferred condition	Use Slide 179.2/7.3.24 Slide 179.2/7.3.24 is a photograph of a total organic carbon analyzer. The unit appears to be in good condition and well maintained.
24. Atomic Absorption - Emission Spectrophotometer a. Preferred condition - related gas cylinders in background should be checked for proper support.	Use Slide 179.2/7.3.25 Slide 179.2/7.3.25 is a photograph of an atomic absorption unit which appears to be properly installed, well maintained and one would suspect providing good results.
	Use Slide 179.2/7.3.26 Slide 179.2/7.3.26 is a blank.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 7: Laboratory Practices

Lesson 3: Laboratory Equipment

Trainee Notebook Contents

References T7.3.1

REFERENCES

1. *Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities*, EPA 430/9-74-002, Municipal Operations Branch, U. S. Environmental Protection Agency, Washington, D.C. (June, 1973).

2. *Federal Register*, Guidelines Establishing Test Procedures for the Analysis of Pollutants.

3. *Inspectors Guide for Evaluation of Municipal Wastewater Treatment Plants*, EPA 430/9-79-010, Municipal Operations Branch, U. S. Environmental Protection Agency, Washington, D.C. (April, 1979).

4. *Operation of Wastewater Treatment Plants*, MOP 11, pages 19-36, 381-410, 463-478, 511-524, Water Pollution Control Federation, Washington, D.C. (1976).

5. *Standard Methods for the Examination of Water and Wastewater*, APHA, AWWA and WPCF (14th edition).

Troubleshooting O & M Problems In Wastewater Treatment Facilities

Unit of Instruction 8: Flow Measurement

Unit 8 of 15 Units of Instruction

Lessons in Unit: 2 Recommended Time: 1 hour

Instructor Overview of the Unit

Rationale for Unit: Accurate and reliable measurement of wastewater flow rates is an essential prerequisite to both plant operations and troubleshooting. The troubleshooter must be able to recognize the importance of flow measurement, know which flows should be measured, how to evaluate the accuracy and reliability of flow measuring devices and how to estimate flows if adequate flow measuring devices are not available in the plant.

Trainee Entry Level Behavior: The trainee should have completed Unit of Instruction 2, *Elements of Troubleshooting*, before beginning this Unit.

Trainee Learning Objectives: At the conclusion of this Unit, the trainee should be able to:

1. Using references, list the reasons why flow volumes into and within a treatment plant are measured and recorded.
2. Using references, identify the type of flows within a treatment plant that should be measured and recorded.
3. Using references, list locations and operations within a plant where flow measurement should be carried out.
4. Using references, identify aspects of treatment plant performance which would be affected by an operator's inability to accurately determine flow rates.
5. From memory, characterize a waste treatment plant as a system and identify the flows within a plant as key linkages between the various plant processes that comprise the overall *waste treatment system*.
6. Using references, list commonly used flow measurement devices and identify the specific applications and uses of flow measurement devices in a treatment plant.

7. From memory, recognize common problems found in flow measurement devices and list their possible causes.

8. Using references, identify indicators of plant performance that may signify unreliable flow measurements.

9. Using references, describe systematic procedures for troubleshooting flow measurement systems in wastewater treatment plants.

10. From memory, describe and carry out observations and tests that may be performed for troubleshooting flow measurement devices.

11. Using references, list and explain corrective actions to be implemented in troubleshooting flow measurement problems.

12. Using references, identify field expedient procedures for measuring flow when existing devices are inadequate or when there are no existing devices.

13. Using references, engage in "creative troubleshooting" to correct problems in flow measurement and to supplement existing means for measuring flows in treatment plants.

Sequencing and Pre-Course Preparation for the Unit: This Unit of Instruction is presented as two lessons.

Lesson 1: Flow Measurement and Treatment Plant Operations

Recommended Time: 30 minutes

Purpose: This lesson emphasizes the importance of knowing the volume of flows into and within a treatment plant as a means of better understanding plant processes, operations and problems and familiarize the trainees with the types of flows to be measured within a treatment plant and with how flow measurements relate to knowledge of plant processes and operations.

Training Facilities:

1. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees.

2. Instructor table with lectern.

3. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.

4. Easel with pad.

5. 35mm carousel projector with remote control changer at instructor table.

6. At least four empty carousel trays.

7. Overhead projector.

8. Chalk, felt-tip markers, erasers, etc.

9. Six to eight chairs randomly spaced at back and sides of room for visitors.

Pre-Course Preparation:

1. Trainee texts

   Order and have available for each trainee seating position

   a. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA 430/9-78-001, Municipal Operations Branch, U. S. Environmental Protection Agency, Washington, D.C. (January, 1978).

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, pages T8.1.1 - T8.1.3, "Measuring Flow Volumes - Impact on Plant Operations."

3. Trainee Handout materials

   Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plans.

   a. None required for Lesson 1.

Instructional Approach: Trainee problem solving with discussion of findings.

Lesson 2: Troubleshooting Treatment Plant Flow Problems

Recommended Time: 30 minutes

Purpose: This lesson presents the basic elements of the Process of Troubleshooting as it relates to operational problems in the measurement of treatment plant flows and stresses the use of flow measurement as a means of solving operational and process control problems within a wastewater treatment plant.

Training Facilities: As specified for Lesson 1.

Pre-Course Preparation:

1. Trainee texts

   a. As specified for Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, pages T8.2.1 - T8.2.2, "Flow Measurement Troubleshooting Guide."

   b. *Trainee Notebook*, page T8.2.3, "Discharge Formulae."

   c. *Trainee Notebook*, page T8.2.4, "References."

3. Trainee Handout materials

   Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plans.

   a. None required for Lesson 1.

Instructional Approach: Illustrated lecture with class discussion.

Presentation Options for the Course Director: The 60 minute unit, *Flow Measurement*, stresses an important aspect of wastewater treatment plant operations. Although the trainees in the course should, by virtue of the entry level requirements, be familiar with flow measurement devices, the emphasis of this lesson may be new to the trainees because it stresses flow measurement as a key to plant operations.

It is recommended that this lesson be presented as designated, in one hour, unless there is a specific need to expand the scope for the particular trainees for whom the course is being presented. Options for modifying the lesson include:

Lesson 1 - *Flow Measurement and Treatment Plant Operation.* This lesson can be enhanced by expanding Section III, which is the trainee exercise on flow measurement and plant performance. If desired, flow diagrams for activated sludge and oxidation lagoons can be used to relate flow measurement to operations of different types of plants.

Lesson 2 - *Troubleshooting Treatment Plant Flow Measurement.* If trainees are unfamiliar with flow measurement devices, slides may be shown which illustrate such devices. Additional time may be used to discuss the proper maintenance and use of common flow measurement devices found in treatment plants.

Summary of Unit of Instruction 8: Flow Measurement

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
1. Flow Measurement and Treatment Plant Operation	1. List purposes of flow measurement and types of flows	1. Flow measurement purposes	1. Follow subject outline with slide series	1. Slides 179.2/8.1.1 - 179.2/8.1.6
30 minutes	2. Identify relationship of knowledge of flows to plant operations	2. Types of flows	2. Trainee group exercise using work sheets & flow diagram	2. "Trainee group work sheet and flow diagram," *Trainee Notebook*, pages T8.1.1-T8.1.3
	3. Characterize flows as linkages between plant processes that comprise the overall waste treatment system.			3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pp. 256-263
2. Troubleshooting Treatment Plant Flow Measurement	1. Identify flow measurement devices	1. Process of troubleshooting	1. Follow subject outline with slide series	1. Slides 179.2/8.2.1 - 179.2/8.2.27
30 minutes	2. Recognize common flow measurement problems	2. Poor flow measurements can create plant operating problems	2. Encourage trainee discussion and participation	2. *Trainee Notebook*, pp. T8.2.1 - T8.2.3, "Troubleshooting Guide and Flow Equations"
	3. Describe troubleshooting procedures for flow measurement problems	3. Flow measurement devices and common problems	3. Use troubleshooting guide by referring to *Trainee Notebook*	3. Process of Troubleshooting Chart, *Trainee Notebook*, page T2.2.8

Summary of Unit of Instruction 8: Flow Measurement (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
	4. Identify field expidients for in-plant flow measurement	4. Systematic troubleshooting guide		4. *Instructor Notebook*, pages 8.2.1 - 8.2.14
		5. Expedients for flow measurment problem solving		5. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pp. 256-263

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 8: Flow Measurement

Lesson 1: Flow Measurement and Treatment Plant Operations

Lesson 1 of 2 lessons Recommended Time: 30 minutes

Purpose: This lesson emphasizes the importance of knowing the volume of flows into and within a treatment plant as a means of better understanding plant processes, operations and problems and familiarize the trainees with the types of flows to be measured within a treatment plant and with how flow measurements relate to knowledge of plant processes and operations.

Trainee Entry Level Behavior: The trainee should have completed Unit of Instruction 2, *Elements of Troubleshooting* before beginning this Unit.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee should be able to:

1. Using references, list the reasons why flow volumes into and within a treatment plant are measured and recorded.
2. Using references, identify the type of flows within a treatment plant that should be measured and recorded.
3. Using references, list locations and operations within a plant where flow measurement should be carried out.
4. Using references, identify aspects of treatment plant performance which would be affected by an operator's inability to accurately determine flow volumes.
5. From memory, characterize a waste treatment plant as a system and identify the flows within a plant as key linkages between the various plant processes that comprise the overall *waste treatment system.*

Instructional Approach: Trainee problem solving with discussion of findings.

Lesson Schedule: The 30 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 5 minutes	Purpose of Flow Measurement
5 - 10 minutes	Types of Flow to Measure
10 - 25 minutes	Flow Measurement and Plant Performance
25 - 30 minutes	Discussion of Flow Measurement Problem

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T8.1.1 - T8.1.3, "Measuring Flow Volumes - Impact on Plant Operations."
2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*
    a. Flow Measurement, pp. 256-263.
    b. Trickling Filters, pp. 77-95.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 8.1.1 - 8.1.7 , Unit 8, Lesson 1.
2. Slides 179.2/8.1.1 - 179.2/8.1.6.

Instructor Materials Recommended for Development: None

Additional Instructor References:

1. *Handbook for Monitoring Industrial Wastewater*, Chapter 7, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (1973).
2. Metcalf and Eddy, Inc., *Wastewater Engineering Treatment Disposal Reuse*, pp. 11-54, McGraw-Hill Company, New York (2nd Edition, 1979).
3. The Texas Water Utilities Association, *Manual of Wastewater Operations* (1971).
4. U. S. Department of Interior, Bureau of Reclamation, *Water Measurement Manual, 2nd Edition*, Available from Superintendent of Documents, U. S. Government Printing Office, Washington, D.C. 20402. Order No. I 27.19/2: W29/2 (1971).
5. Leopold Stevens, Inc., *Hydrographic Data Book*, 8th Edition, P. O. Box 25347, Portland, Oregon 97225.
6. Manning Environmental Corporation, *Flow Tables for Circular Pipes*, 112 Dakota Avenue, Santa Criz, California 95060.

7. King, W. K. and Brater, E. F., *Handbook of Hydraulics*, 5th Edition, McGraw-Hill Company, New York (1963).

8. Davis, D. V. and Sorensen, D. E., *Handbook of Applied Hydraulics*, 3rd Edition, McGraw-Hill Company, New York (1969).

9. Bauer, S. W. and Graf, W. H., "Free Overfall as Flow Measuring Device," in *Proceedings: American Society of Civil Engineers, Journal, Irrigation Drainage Division, 97 IR*, 7987 (1971).

10. National Bureau of Standards, U. S. Department of Commerce, *A Guide to Methods and Standards for the Measurement of Water Flow* (1975).

11. Office of Research and Monitoring, U. S. Environmental Protection Agency, "Flows Augmenting Effects of Additives on Open Channel Flows," Environmental Protection Technology Series, EPA-R2-83-238, Washington, D.C. 20460 (1973).

12. Municipal Operations Branch, U. S. Environmental Protection Agency, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA 430/9-78-001, Washington, D.C. (January, 1978).

13. *Operation of Wastewater Treatment Plants, MOP 11*, pp. 381-410, Water Pollution Control Federation, Washington, D.C. (1976).

14. *Instrumentation in Wastewater Treatment Plants, MOP 21*, Water Pollution Control Federation, Washington, D.C. (1978).

15. *Wastewater Treatment Plant Design, MOP 8*, Water Pollution Control Federation, Washington, D.C. (1977).

Classroom Set-Up:

1. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees.

2. Instructor table with lectern.

3. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.

4. Easel with pad.

5. 35mm carousel projector with remote control changer at instructor table.

6. At least four empty carousel trays.

7. Overhead projector.

8. Chalk, felt-tip markers, erasers, etc.

9. Six to eight chairs randomly spaced at back and sides of room for visitors.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
I. Purposes of Flow Measurement (5 minutes)	Use Slide 179.2/8.1.1 Slide 179.2/8.1.1 is a blank.
A. Introduction	
1. Use Slide 179.2/8.1.2 to introduce subject. Use opening 5 minutes to "warm up" class for discussion.	Use Slide 179.2/8.1.2 Slide 179.2/8.1.2 is a word slide which reads:
2. Have class contribute input on why flow measurement is important. Have a student record reasons on chalkboard.	"Purposes of Flow Measurement"
3. After 5 minutes, go to Slide 179.2/8.1.3 with prepared list of purposes.	
B. Review purposes of flow measurement	Use Slide 179.2/8.1.3 Slide 179.2/8.1.3 is a word slide which reads: "Purposes of Flow Measurement Measure Organic and Hydraulic Loads Provide Operating and Performance Data Process Control Troubleshoot Problems Measure Loads by Source Compute Costs Build Long Term Record"
II. Types of Flows to be Measured (5 minutes)	Use Slide 179.2/8.1.4 Slide 179.2/8.1.4 is a word slide which reads:
A. Introduction	
1. Use Slide 179.2/8.1.4 to introduce sub-subject.	"Types of Flows to Measure"
2. Seek student discussion on what flows normally should be measured in treatment plant operations.	
B. Types of Flow Measurement	Use Slide 179.2/8.1.5 Slide 179.2/8.1.5 is a word slide which reads:
1. Influent flows	
a. Domestic waste	

LESSON OUTLINE

    b. Industrial waste
    c. Storm flow
    d. Infiltration
    e. Septage
2. Internal flows
    a. Distribution to tanks
    b. Uniform discharge through ports, weirs, etc.
3. Side streams
    a. Return activated sludge
    b. Waste activated sludge
    c. Filtrates
    d. Elutriates
    e. Supernates
4. Chemical feeds
    a. Disinfection
    b. Coagulants
    c. pH control
    d. Sludge conditioners
5. Effluent

III. Flow Measurement and Plant Performance (15 minutes)

A. Assign trainees to work in pre-designated trainee groups.

KEY POINTS & INSTRUCTOR GUIDES

"Types of Flows to Measure

Influent
Internal - to Balance Flow
  Between Parallel Components
Side Streams
Chemical Feeds
Effluent"

Use Slide 179.2/8.1.6
Slide 179.2/8.1.6 is a blank.

Guide: The purpose of this section is to highlight the following:

LESSON OUTLINE

B. Refer trainees to problem work sheets in *Trainee Notebook*:

1. Page T8.1.1, Trickling Filter Flow Diagram.
2. Pages T8.1.2-T8[illegible].3, Problem Answer Sheets

C. Have trainee groups complete the answer sheets for this problem. Stress the importance of discussion between all of the members of each trainee group.

D. After 15 minutes, proceed to a class discussion of the results of the problem.

IV. Discussion of Flow Measurement Problem (5 minutes)

A. Have trainees discuss the results of the assigned problem.

B. Stress discussion of Question 2 - Treatment performance affected by lack of accurate flow measurement.

KEY POINTS & INSTRUCTOR GUIDES

1. Treatment plants function as a system - linked by a variety of flows.
2. Accurate flow measurements are needed to understand the waste treatment system.
3. Plant performance may be affected if there are not good flow measurements.

Refer class to *Field Measurement for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*,

a. Flow Measurement, pp 256-263
b. Trickling Filters, pp. 77-95

Key Point: Good flow measurement is one key to plant performance.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 8: Flow Measurement

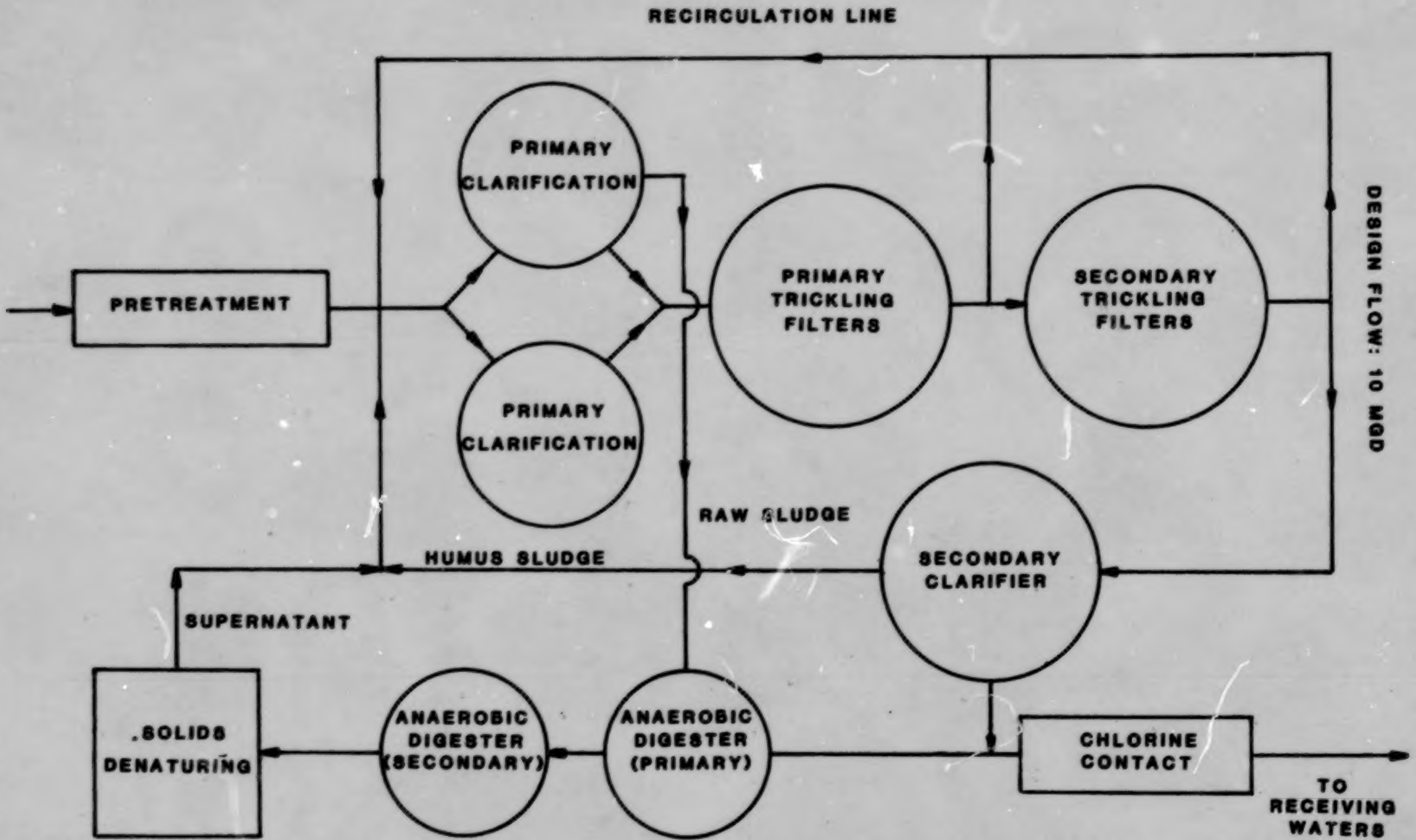
Lesson 1: Flow Measurement and Treatment Plant Operations

Trainee Notebook Contents

Trickling Filter Flow Diagram T8.1.1

Measuring Flow Volumes - Impact on Plant Operations: Answer Sheet T8.1.2

T8.1.1



TRICKLING FILTER FLOW DIAGRAM

Measuring Flow Volumes - Impact on Plant Operations

Answer Sheet

GROUP # ____

1. Using the Trickling Filter Flow Diagram, identify the following major plant flows, by numbering key points on the flow diagram according to the type of flow as follows.

   1. Influent flows
   2a. Internal flows - parallel distribution
   2b. Internal flows - series distribution
   3. Side streams (sludge, supernatant, etc.)
   4. Chemical feeds - actual or possible
   5. Effluent

2. For each of the following processes, determine whether plant performance would be affected by the operator's inability to accurately measure flow volumes identified in question 1.

Process	Yes or No Performance Affected	Possible Indicators of Poor Performance
a. Pretreatment		
b. Primary Clarification		
c. Trickling Filter		

Answer Sheet (Continued)

Group # ____

Process	Yes or No Performance Affected	Possible Indicators of Poor Performance
d. Secondary Clarifier		
e. Digesters		
f. Chlorination		
g. Effluent Quality		

3. For each flow identified in question 1, identify a flow measurement device that would normally be used.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 8: Flow Measurement

Lesson 2: Troubleshooting Treatment Plant Flow Problems

Lesson 2 of 2 lessons Recommended Time: 30 minutes

Purpose: This lesson presents the basic elements of the Process of Troubleshooting as it relates to operational problems in the measurement of treatment plant flows and stresses the use of flow measurement as a means of solving operational and process control problems within a wastewater treatment plant.

Trainee Entry Level Behavior: The trainee should have completed Unit 8, Lesson 1 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee should be able to:

1. Using references, list commonly used flow measurement devices and identify the specific applications and uses of flow measurement devices in a treatment plant.
2. From memory, recognize common problems found in flow measurement devices and list their possible causes.
3. Using references, identify indicators of plant performance that may signify unreliable flow measurements.
4. Using references, describe systematic procedures for troubleshooting flow measurement systems in wastewater treatment plants.
5. From memory, describe and carry out observations and tests that may be performed for troubleshooting flow measurement devices.
6. Using references, list and explain corrective actions to be implemented in troubleshooting flow measurement problems.
7. Using references, identify field expedient procedures for measuring flow when existing devices are inadequate or when there are no existing devices.
8. Using references, engage in "creative troubleshooting" to correct problems in flow measurement and to supplement existing means for measuring flows in treatment plants.

Instructional Approach: Illustrated lecture with class discussion.

Lesson Schedule: The 30 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 5 minutes	Approach to Troubleshooting
5 - 15 minutes	Identifying Flow Measurement Devices and Common Problems
15 - 20 minutes	Systematically Troubleshooting Flow Measurement
20 - 25 minutes	Flow Measuring Expedients
25 - 30 minutes	Lesson Summary

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T8.2.1 - T8.2.2, "Flow Measurement Troubleshooting Guide."

2. *Trainee Notebook*, page T8.2.3, "Discharge Formuale."

3. *Trainee Notebook*, page T8.2.4, "References."

4. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 256-263.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 8.2.1 - 8.2.14, Unit 8, Lesson 2.

2. Slides 179.2/8.2.1 - 179.2/8.2.27.

Instructor Materials Recommended for Development: If this lesson is expanded the instructor should develop schematics and photographic illustrations of various flow measuring devices and systems with illustrations of common problems.

Additional Instructor References: As specified for Unit 8, Lesson 1.

Classroom Set-Up: As specified for Unit 8, Lesson 1.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
I. Approach to Troubleshooting Flow Measurement Problems (5 minutes) A. Refer class to Process of Troubleshooting Guide in *Trainee Notebook*, page T2.2.8. B. The instructor should focus on the overall Process of Troubleshooting for solving plant problems and then on the specific possibility that deficiencies in flow measurement may be partially responsible. C. Relate troubleshooting of flow measurement to the Process of Troubleshooting.	Use Slide 179.2/8.2.1 Slide 179.2/8.2.1 is a blank.
1. Use Slide 179.2/8.2.2 to discuss initial steps in troubleshooting.	Use Slide 179.2/8.2.2 Slide 179.2/8.2.2 is a word slide which reads: "Initial Steps in Troubleshooting Flow Measurement Problems What Do Past Records Indicate? What Does the Operator Think? What Observations and Tests Need to be Made? How is Plant Performance Affected? What Measurement Devices Exist?"
2. Use Slide 179.2/8.2.3 to list some possible findings during the initial troubleshooting steps.	Use Slide 179.2/8.2.3 Slide 179.2/8.2.3 is a word slide which reads: "What Symptoms Exist of Plant Problems? Low Removals Frequent Breakdowns Excessive Maintenance Poor Sludges Nuisances"
3. Use Slide 179.2/8.2.4 to highlight fact that inaccurate flow measurement could be a contributing factor to poor process control decision making.	Use Slide 179.2/8.2.4 Slide 179.2/8.2.4 is a word slide which reads:

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
	"Can Alternative Causes of Plant Problems Be Found? Can Poor Flow Measurements Be Possibly Listed as a Cause for Plant Problems?"
4. Use Slide 179.2/8.2.5 to list problems which might occur if flows are unknown or inaccurately measured.	Use Slide 179.2/8.2.5 Slide 179.2/8.2.5 is a word slide which reads: "Can Poor Flow Measurements Be Responsible For Hydraulic Overloads Organic Overloads Unbalanced Flows Inadequate Disinfection Poor Sludge Treatment"
II. Identifying Flow Measurement Devices and Common Problems Associated with Them (10 minutes) A. Refer class to pages 256-263, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* for illustrations of flow measuring devices.	Note: Students with the proper prerequisites should have sufficient knowledge about flow measurement devices. Therefore, it is not necessary to describe flow measurement devices in detail. Trainees may be referred to other sources for additional information. Note: Picture slides of various flow measurement devices may be added if they can be obtained.
B. Briefly discuss components of flow measuring and recording system.	Use Slide 179.2/8.2.6 Slide 179.2/8.2.6 is a word slide which reads: "Elements of a Complete Flow Measurement System Primary Response Mechanism Transmission of Response Signal Recording Device Totaling Device"
C. Use Slide 179.2/8.2.7 to illustrate components of a flow measuring and recording system.	Use Slide 179.2/8.2.7 Slide 179.2/8.2.7 is a schematic:

LESSON OUTLINE

1. Sequence of events in flow measurement and recording.

2. Possible error points

    a. Primary device is inaccurate

    b. Conversion error at primary response mechanism

    c. Conversion or transmission error

    d. Conversion or calibration error at recorder or totalizer.

E. Problems with Flow Measuring Devices

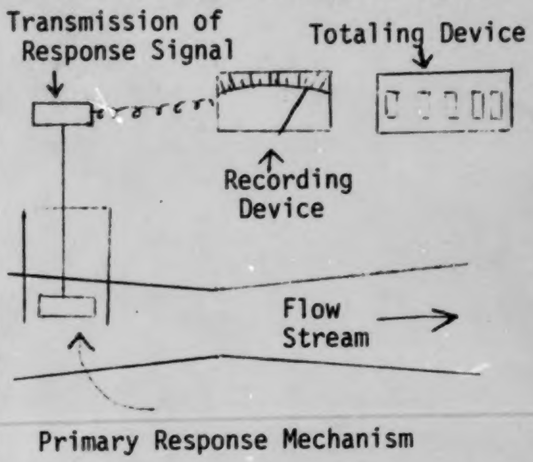
1. Use Slide 179.2/8.2.8 to identify common measuring devices.

2. Flow Meters

    a. Use Slide 179.2/8.2.9 to identify common types of meters.

KEY POINTS & INSTRUCTOR GUIDES

"Schematic Flow Measurement System



Use Slide 179.2/8.2.8
Slide 179.2/8.2.8 is a word slide which reads:

"Common Types of Flow Measurement Devices

Meter
Constrictors
  Flumes
  Weirs
  Nozzles
Pumps"

Use Slide 179.2/8.2.9
Slide 179.2/8.2.9 is a word slide which reads:

"Flow Meters - Common Varieties

Magnetic
  Gaining wide use for inflows, recirculation and sludge
Venturi
Turbine"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
b. Use Slide 179.2/8.2.10 to list common meter problems.	Use Slide 179.2/8.2.10 Slide 179.2/8.2.10 is a word slide which reads: "Common Meter Problems Improper Location Improper Size Unsuitable for Material Being Measured Poor Instrumentation No Totalizer Unreliable Due to Age or Condition"
c. Encourage class discussion of each problem with emphasis on evaluation procedures, sources of specific information, what to do if the problem is encountered.	
d. Use Slide 179.2/8.2.11 to list possible corrective actions.	Use Slide 179.2/8.2.11 Slide 179.2/8.2.11 is a word slide which reads: "Corrective Actions for Meters Good Continual Cleaning and Maintenance Proper Installation at the Right Location Calibrate and Monitor Transmission and Recording Elements, Replace or Repair if Necessary"
3. Flumes and Nozzles a. Identify Parshall flume and Kennison Flow Nozzle	Use Slide 179.2/8.2.12 Slide 179.2/8.2.12 is a word slide which reads: "Flumes and Nozzles Parshall Flume Widely used due to simplicity and accuracy Kennison Flow Nozzle Measures flow in pipes not running full"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
b. Common problems	Use Slide 179.2/8.2.13 Slide 179.2/8.2.13 is a word slide which reads: "Common Flume Problems Improper Location or Size Turbulence or Obstructions Upstream Float Location, Malfunction, Freezing Buildup of Solids Downstream Submergence Poor Instrumentation"
c. Encourage discussion on evaluation, sources of data and what to do.	
d. Corrective actions	Use Slide 179.2/8.2.14 Slide 179.2/8.2.14 is a word slide which reads: "Corrective Actions for Flumes Calibration Removal of Obstructions, Solids Minimize Turbulence
4. Weirs a. Identify types	Use Slide 179.2/8.2.15 Slide 179.2/8.2.15 is a word slide which reads: "Weirs Rectangular Cipolletti (Trapezoidal) V Notch Proportional"
b. Common problems	Use Slide 179.2/8.2.16 Slide 179.2/8.2.16 is a word slide which reads: "Common Weir Problems Overall Accuracy Buildup of Solids Not Calibrated Poor Design or Installation No charts or nomographs"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
c. Encourage discussion on evaluation, source of data and what to do.	
d. Corrective actions	Use Slide 179.2/8.2.17 Slide 179.2/8.2.17 is a word slide which reads: "Corrective Actions for Weirs Calibration Development of Accurate Charts Cleaning and Maintenance Minimize Turbulence and Surge Action"
5. Pumps for Flow Measurement	
a. Problems	Use Slide 179.2/8.2.18 Slide 179.2/8.2.18 is a word slide which reads: "Pumps - Problems with Using Pumps to Measure Flows No True Knowledge of Pump Characteristics No Counters on Positive Displacement Pumps No Timers on Fixed Speed Units No Individual Meters"
b. Encourage discussion	
c. Corrective actions	Use Slide 179.2/8.2.19 Slide 179.2/8.2.19 is a word slide which reads: "Corrective Actions for Pumps Install Meters if Possible at Key Locations Install Counters and Timers Calibrate by Measuring Actual Flow Volumes and Rates Calibrate to Allow Visual Observations with Staff Groups"

LESSON OUTLINE

III. Systematically Troubleshooting Flow Measurement at Treatment Plants (5 minutes)

Using the Flow Measurement Troubleshooting Guide:

A. Analyse Plant Flow Measurement Capability

1. Review plans and flow diagrams
    - a. Define plant processes, operations and sub-systems.
    - b. Locate sources and discharge points of all streams and side streams.
    - c. Study plant flexibility with respect to possible mode change.
    - d. Locate measuring devices and evaluate their adequacy with respect to:
        - 1) Type of device used
        - 2) Location
        - 3) Size
        - 4) Recording and totaling capability
        - 5) Overall installation
2. Tour facility
    - a. Observe physical layout and location of measuring devices, valves, pumps and tanks.
    - b. Discuss plant performance with operator, plant personnel.
    - c. Seek the opinions of plant personnel.
    - d. Learn color coding, labeling and unit designations
    - e. Examine measuring devices, their installation and condition.
3. Examine flow charts

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/8.2.20
Slide 179.2/8.2.20 is a blank.

Refer class to *Trainee Notebook*, T8.2.1.,"Flow Measurement Troubleshoot Guide" for this section of the outline. Briefly review this outline.

Note: This is presented as a systematic guide to trainees for troubleshooting flow measurement problems at treatment plants.

Key Point: Use the Process of Troubleshooting with respect to flow measurement.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDES

   - a. Evaluate trends.
   - b. Check for storm response.
   - c. Identify unusual deviations.
- 4. Study manufacturer's recommendations for user maintenance.
   - a. Review maintenance records
   - b. Calibration history
- 5. Examine instrumentation
   - a. Check for evidence of operator tampering
   - b. Calibration history
- 6. Inspect weirs and flumes
   - a. Measure appropriate heads.
   - b. Check instrument readings.
   - c. Check for obstructions, turbulence and condition of device.
   - d. Disturb floats, check for response on flow charts.
   - e. Observe surge action.

B. Formulate Alternatives

- 1. Possible causes to plant problems
   - a. Poor control over specific treatment processes.
   - b. Organic overloading
   - c. Poor management and administration
   - .
   - .
   - n. Difficulties or inaccuracies in measuring flows

2. Prioritize alternatives and corrective actions.

3. Confirm opinion if possible.

4. Get outside help if necessary.

5. There may not be one single "right" answer.

C. Take appropriate corrective actions, observe and test. With regard to flow measurement problems, this may mean

1. Major Corrective Action

   a. Install metering equipment at points where flow data is necessary.

   b. Repair existing flow measurement systems.

   c. Calibrate existing flow measurement systems.

   d. Modify or replace systems for transmitting, recording or totaling flow data.

   e. Correct faulty installations and conditions which cause flow measurement devices to operate improperly.

   f. Cleaning and preventive maintenance.

   g. Develop accurate charts.

   h. Install counters and timers on pumps.

2. Expedient Actions on a Temporary Basis - Until Permanent Improvement Can Be Made

   a. Improve or "fix-up" present system

   b. Install temporary recorders

   c. Calibrate existing devices

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
d. Install devices to facilitate quick measurements in the future.	
e. Install temporary measuring systems.	
f. Calculate flows from pipe or channel measurements.	
g. Compute flows using pump curves.	
3. Flow balancing and equalization within the plant	
a. Equalize flows to parallel plant units	
b. Increase or decrease flows where necessary for process control.	
c. Balance solid loadings by using centrifuge.	
d. Modify chemical feed rates.	
IV. Flow Measurement Expedients (Or what to do when there's nothing else to do) (5 minutes)	Guide: Instructor should maximize trainee input into this section.
A. Ask trainees to discuss what they would do to measure flows at plants with non-existent or inadequate flow measurement capability. If necessary - use the following 5 slides to cover this subject.	
B. Possible Expedients	Use Slide 179.2/8.2.21 Slide 179.2/8.2.21 is a word slide which reads: "Flow Measurement Expedients for Plant Troubleshooting Improve Present Systems to Produce Better Results Calibrate Existing Systems Provide for Future Measurements Set-Up Temporary Flow Measurement Devices"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
C. Improve Present System (Encourage class discussion with the "others" element on slide.)	Use Slide 179.2/8.2.22 Slide 179.2/8.2.22 is a word slide which reads: "Expedients - Improvement of Present Systems Baffle Turbulence and Surges Clean and Maintain Systems Install Temporary Recorders If Necessary Others"
D. Calibration	Use Slide 179.2/8.2.23 Slide 179.2/8.2.23 is a word slide which reads: "Expedients - Calibration Calibrate Weirs and Flumes Calibrate Pumps by Timing Periods Required to Fill Known Volumes at Various Pumping Speeds Others"
E. Future Measures	Use Slide 179.2/8.2.24 Slide 179.2/8.2.24 is a word slide which reads: "Expedients - Future Measurements Install Counters on Positive Displacement Pumps Install Staff Gauges at Time Flow Measurement Equipment is Calibrated Others"
F. Temporary Devices	Use Slide 179.2/8.2.25 Slide 179.2/8.2.25 is a word slide which reads: "Expedients - Temporary Devices Install Temporary Weirs or Flumes In Collection System In Plant At Discharge

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
	Calculate Flows - California Pipe Method or Other Methods Use Pump Curves to Compute Flows Others"
V. Lesson Summary (5 minutes)	Use Slide 179.2/8.2.26 Slide 179.2/8.2.26 is a word slide which reads: "Summary - Troubleshooting for Flow Measurement Flow Measurement is a Key to Plant Operations and Troubleshooting Impact on Plant Operations Devices are a Part of Flow Measurement Systems Systematic Troubleshooting Approach Applies to Flow Measurement Field Expedients May Be Necessary"
	Use Slide 179.2/8.2.27 Slide 179.2/8.2.27 is a blank.

611

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 8: Flow Measurement

Lesson 2: Troubleshooting Treatment Plant Flow Measurement

Trainee Notebook Contents

Flow Measurement Troubleshooting Guide. T8.2.1

Discharge Formulae T8.2.3

References T8.2.4

Flow Measurement Troubleshooting Guide

Note: This is presented as a systematic guide to trainees for troubleshooting flow measurement problems at treatment plants.

I. Analyze Plant Flow Measurement Capability

A. Review plans and flow diagrams

1. Define plant processes, operations and sub-systems
2. Locate sources and discharge points of all streams and side streams
3. Study plant flexibility with respect to possible mode change
4. Locate measruing devices and evaluate their adequacy with respect to:
    a. type of device used
    b. location
    c. size
    d. recording and totalling capability
    e. overall installation

B. Tour facility

1. Observe physical layout and location of measuring devices, valves, pumps and tanks
2. Discuss plant performance with operator, plant personnel
3. Seek the opinions of plant personnel
4. Learn color coding, labeling and unit designations
5. Examine measuring devices, their installation and condition

C. Examine flow charts

1. Evaluate trends
2. Check for storm response
3. Identify unusual deviations

D. Study manufacturer's recommendations for user maintenance

1. Review maintenance records

E. Examine instrumentation

1. Check for evidence of operator tampering

F. Inspect weirs and flumes

1. Measure appropriate heads
2. Check instrument readings
3. Check for obstructions, turbulence and condition of device
4. Disturb floats, check for response on flow charts
5. Observe surge action

II. Formulate Alternatives

A. Possible causes to plant problems

1. Poor control over specific treatment processes
2. Organic overloading
3. Poor management and administration
.
.
n. Difficulties or inaccuracies in measuring flows

B. Prioritize alternatives and corrective actions

C. Confirm opinion if possible

D. Get outside help if necessary

E. There may not be one single "right" answer

III. Take appropriate corrective actions, observe and test. With regard to flow measurement problems, this may mean:

A. Major corrective action

1. Install metering equipment at points where flow data is necessary
2. Repair existing flow measurement systems
3. Calibrate existing flow measurement systems
4. Modify or replace systems for transmitting, recording or totalling flow data
5. Correct faulty installations and conditions which cause flow measurement devices to operate improperly
6. Cleaning and preventive maintenance
7. Develop accurate charts
8. Install counters and timers on pumps

B. Expedient actions on a temporary basis - until permanent improvement can be made

1. Improve or "fix-up" present systems
2. Install temporary recorders
3. Calibrate existing devices
4. Install devices to facilitate quick measurements in the future
5. Install temporary measuring systems
6. Calculate flows from pipe or channel measurements
7. Compute flows using pump curves

C. Flow balancing and equalization within the plant

1. Equalize flows to parallel plant units
2. Increase or decrease flows where necessary for process control
3. Balance solid loadings by using centrifuge
4. Modify chemical feed rates

DISCHARGE FORMULAE*

1. Basic Flow Formula: $Q = AV$
2. Mannings Formula: $V = \frac{1.486}{n} R^{2/3} S^{1/2}$ (Flow in pipes)
3. 90° V-notch weir: $Q = 2.52 H^{2.47}$ cfs
4. 60° V-notch weir: $Q = 1.43 H^{2.5}$ cfs
5. Proportional weir: $Q = 7.57 mH$ cfs
6. Rectangular weir: $Q = 3.33 LH^{1.5}$ cfs
7. Cippoletti weir: $Q = 3.367 LH^{1.5}$ cfs (trapazoidal)
8. Parshall Flume: $Q = 4 WH_A^{1.52W^{0.026}}$ cfs
9. Venturi meter: $Q = \frac{C_v \Pi d_2^2}{4} \sqrt{\frac{2gh}{1 - \frac{d_2}{d_1}^4}}$
10. Orifice: $Q = C_d A \quad 2g H$
11. Parabolic flume } Calibrated by
12. Magnetic meter } manufacturer
13. California Pipe Method }
14. Board of Water Engineers Method } nomographs
15. Volume Displacement Method

Q = flow
A = cross sectional area
V = velocity
n = roughness coef.
R = hydraulic radius
S = slope
H, h = head
m = width at the point where $H = 1$ ft

L = length
W = throat width
C_v = velocity coef.
g = gravity constant (32.2)
d = diameter of pipe
C_d = discharge coef.

*Courtesy of the Texas Water Quality Board, Austin, Texas

REFERENCES

1. Bauer, S. W., and Graf, W. H., "Free Overfall as Flow Measuring Device," in *Proceedings: American Society of Civil Engineers, Journal, Irrigation Drainage Division*, 97 IR,7987 (1971).

2. Davis, D. V. and Sorensen, D. E., *Handbook of Applied Hydraulics*, 3rd Edition, McGraw-Hill, New York (1969).

3. *Handbook for Monitoring Industrial Wastewater*, Chapter 7, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (1973).

4. *Instrumentation in Wastewater Treatment Plants, MOP 21*, Water Pollution Control Federation, Washington, D.C. (1978).

5. King, W. K. and Brater, E. F., *Handbook of Hydraulics*, 5th Edition, McGraw-Hill, New York (1963).

6. Leopold Stevens, Inc., *Hydrographic Data Book*, 8th Edition, P. O. Box 25347, Portland, Oregon 97225.

7. Manning Environmental Corporation, *Flow Tables for Circular Pipes*, 112 Dakota Avenue, Santa Cruz, California 95060.

8. Metcalf and Eddy, Inc., *Wastewater Engineering Treatment Disposal Reuse*, pp. 11-54, Mc-Graw Hill, New York (2nd edition, 1979).

9. Municipal Operations Branch, U. S. Environmental Protection Agency, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA 430/9-78-001, Washington, D.C. (January, 1978).

10. National Bureau of Standards, U. S. Department of Commerce, *A Guide to Methods and Standards for the Measurement of Water Flow* (1975).

11. Office of Research and Monitoring, U. S. Environmental Protection Agency, "Flow Augmenting Effects of Additives on Open Channel Flows," Environmental Protection Technology Series, EPA-R2-83-238, Washington, D.C. (1973).

12. *Operation of Wastewater Treatment Plants, MOP 11*, pp. 381-410, Water Pollution Control Federation, Washington, D.C. (1976).

13. The Texas Water Utilities Association, *Manual of Wastewater Operations*, Austin, Texas (1971).

14. U. S. Department of Interior, Bureau of Reclamation, *Water Measurement Manual, 2nd Edition*, U. S. Government Printing Office, Washington, D.C. (1971). Order No. 1 27.19/2: W 29/2.

15. *Wastewater Treatment Plant Design, MOP 8*, Water Pollution Control Federation, Washington, D.C. (1977)

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 9: Chemical Additions

Unit 9 of 15 Units of Instruction

Lessons in Unit: 2 Recommended Time: 2 hours

Instructor Overview of the Unit

Rationale for Unit: Chemicals are frequently used to upgrade the performance of existing treatment plants or as advanced treatment process add-ons to traditional treatment plants to achieve removal of pollutants and nutrients not normally removed by traditional methods. Chemical additions may solve some treatment problems but they may create more problems if used indiscriminantly. This unit focuses on key issues to be considered when using chemical additions as a troubleshooting aid or as an advanced treatment technology.

Trainee Entry Level Behavior: The trainee should have achieved the learning objectives specified for Unit of Instruction 2, *Elements of Troubleshooting* before beginning this unit.

Trainee Learning Objectives: At the conclusion of this unit, the trainee will be able to:

1. From memory, list and describe the purposes and benefits of chemical additions in wastewater treatment and describe problems which may result from chemical addition.

2. From memory, describe the jar test and explain how it is used to determine chemical dosages and describe the limitations when applying jar test results to plant situations.

3. Using references, describe how the process of troubleshooting is applied to evaluation of chemical conditioning systems in treatment plants.

4. From memory, describe the effects of chemical additions on traditional wastewater treatment processes.

5. List the factors which should be considered in evaluating chemical treatment systems and in making the decision to use chemicals to upgrade plant performance.

6. List and identify trouble indicators in chemical addition.
7. List probable causes to trouble indicators in chemical addition.
8. Describe troubleshooting checks to determine the nature of chemical addition problems.
9. List possible solutions to common chemical addition problems.

Sequencing and Pre-Course Preparation for the Unit: This Unit of Instruction is presented as two lessons as follows.

Lesson 1: Using Chemicals to Upgrade Treatment Plants

Recommended Time: 60 minutes

Purpose: Chemical additives are widely used as a means for upgrading the performance of wastewater treatment facilities. This lesson reviews chemicals commonly used in wastewater treatment facilities and describes how chemical additions can be used by the operator or the troubleshooter to improve treatment process performance.

Training Facilities:

1. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees.
2. Instructor table with lectern.
3. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.
4. Easel with pad.
5. 35mm carousel projector with remote control changer at instructor table.
6. At least four empty carousel trays.
7. Overhead projector.
8. Chalk, felt-tip markers, erasers, etc.
9. Six to eight chairs randomly spaced at back and sides of room for visitors.

Pre-Course Preparation

1. Trainee Texts

   a. Order and have available at each trainee seating position *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA 430/9-78-001, Municipal Operations Branch, U.S. Environmental Protection Agency, Washington, D.C. (January, 1978).

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, pages T9.1.1 - T9.1.5.

3. Trainee Handout materials

   Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plans.

   a. None required for Lesson 1.

Instructional Approach: Illustrated lecture.

Lesson 2: Troubleshooting Plants with Chemical Additions

Recommended Time: 60 minutes

Purpose: This lesson discusses application of the Process of Troubleshooting to plants which use chemical treatment. The lesson is loosely structured to permit a maximum of class participation in an extended question and answer period.

Training Facilities: As specified for Unit 9, Lesson 1.

Pre-Course Preparation

1 Trainee Texts

   a. As specified for Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   1. *Trainee Notebook*, page T9.2.1, "References."

3. Trainee Handout materials

Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plan.

a. None required for Lesson 2.

Instructional Approach: Illustrated lecture with questions and open discussion.

Presentation Options for the Course Director: The 120 minute unit, *Chemical Additions*, is one of the less essential units to this course. It is included because the course developers believe that troubleshooters will, in the future, increasingly confront such plants and will be in a position to provide needed technical assistance. In areas where it is not likely to be useful to field personnel, this lesson may be excluded from the course.

Major expansions of the unit would be possible, if desired, and if time permitted. However, additional course material would be necessary. Subjects covered in the lesson which could be expanded include:

Lesson 1 - Using Chemicals to Upgrade Treatment Plants

Aids to Secondary Treatment. This is one area where the instructor could go into great depth.

Determining Proper Chemicals and Their Doses

Applying Chemicals - Chemical feed equipment could be studied in detail for troubleshooting purposes.

Lesson 2 - Troubleshooting Plants with Chemical Additions

Specific troubleshooting problems in advanced waste treatment

For an overall course presentation of between 28 and 40 hours, it is recommended that this unit be kept at two hours without expanding its scope.

If this topic is of great importance to the particular trainee group, and if time permits, the unit can be taught in a 2 hour time period. Every effort should be made to increase student discussion and participation in the lesson.

Summary of Unit of Instruction 9: Chemical Additions

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
1. Using Chemicals to Upgrade Treatment Plants 60 minutes	1. List and describe purposes and benefits of chemical additions	1. Purpose of chemical additions	1. Follow subject outline. Use prepared slide series.	1. Slides 179.2/9.1.1 - 179.2/9.1.32
	2. Describe tests, including jar tests, needed to determine proper chemicals and doses	2. Impact of chemical additions	2. Use *Trainee Notebook* materials at appropriate points in lesson	2. *Instructor Notebook*, pages 9.1.1 - 9.1.18
	3. Recognize factors in considering chemical additions	3. Determine proper chemicals and doses	3. Encourage student discussion and questions	3. *Trainee Notebook*, pages T9.1.1 - T9.1.5
	4. Know the impacts of chemical additions on a conventional plant	4. Factors considered in applying chemicals		4. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*
		5. Consequences on plant of chemical additives		
2. Troubleshooting Plants with Chemical Additions	1. List and identify trouble indicators in operations using chemical additions	1. Troubleshooters must be experienced with chemical additions if they are to assist	1. Follow subject outline. Use prepared slide series	1. Slides 179.2/9.2.1 - 179.2/9.2.9

Summary of Unit of Instruction 9: Chemical Additions (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
60 minutes	2. Know which observations and tests to use in troubleshooting chemical additions	2. The systematic Process of Troubleshooting is particularly important	2. Emphasize the Process of Troubleshooting	2. *Instructor Notebook*, pages 9.2.1 - 9.2.8
	3. Determine alternative corrections for problems with chemical additions	3. Troubleshooters must know the expected plant performance	3. Trainee discussion	3. Process of Troubleshooting Chart, *Trainee Notebook*, page T2.2.8
				4. *Trainee Notebook*, page T9.2.1, "References"
				5. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*

624

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 9: Chemical Additions

Lesson 1: Using Chemicals to Upgrade Treatment Plants

Lesson 1 of 2 Recommended Time: 60 minutes

Purpose: Chemical additives are widely used as a means for upgrading the performace of wastewater treatment facilities. This lesson reviews chemicals commonly used in wastewater treatment facilities and describes how chemical additions can be used by the operator or the troubleshooter to improve treatment process performance.

Trainee Entry Level Behavior: The trainee should have achieved the learning objectives specified for Unit of Instruction 2: *Elements of Troubleshooting* before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. From memory, list and describe the purposes and benefits of chemical additions in wastewater treatment and describe problems which may result from chemical additions.
2. From memory, describe the jar test and explain how it is used to determine chemical dosages and describe the limitations when applying jar test results to plant situations.
3. Using references, describe how the process of troubleshooting is applied to evaluation of chemical conditioning systems in treatment plants.
4. From memory, describe the effects of chemical additions on traditional wastewater treatment processes.

Instructional Approach: Illustrated lecture

Lesson Schedule: The 60 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 10 minutes	Introduction to Chemical Additions
10 - 20 minutes	Impact of Chemical Additives
20 - 35 minutes	Determining Proper Chemical and Their Doses
35 - 50 minutes	Applying Chemicals
50 - 60 minutes	Consequences of Chemical Additives

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T9.1.1 - 9.1.5.
2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*
    a. Chemical Feeding and Conditioning, pages 202-228.
    b. Rapid Mixing and Flocculation, pages 229-234.
    c. Activated Carbon Adsorption, pages 171-181.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 9.1.1 - 9.1.18, Unit 9, Lesson 1.
2. Slides 179.2/9.1.1 - 179.2/9.1.32.

Instructor Materials Recommended for Development: None

Additional Instructor References:

1. *Operation of Wastewater Treatment Plants, MOP 11*, Water Pollution Control Federation, Washington, D.C. (1976).
2. *Nitrogen Control*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, OH (1975).
3. *Phosphorous Removal*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, OH (1971).
4. *Carbon Adsorption*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, OH (1973).
5. *Suspended Solids Removal*, Technology Transfer, U.S. Environmental Protection Agency, Cincinnati, OH (1975).
6. *Upgrading Existing Wastewater Treatment Facilities*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, OH (1974).
7. *Sulfide Control in Sanitary Sewerage Systems*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, OH (1974).
8. Metcalf and Eddy, Inc., *Wastewater Engineering Treatment Disposal Reuse*, McGraw-Hill Book Co., New York (2nd edition, 1979).

Classroom Set-Up:

1. Large room, preferably 40' by 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees.
2. Instructor table with lectern.
3. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.
4. Easel with pad.
5. 35mm carousel projector with remote control changer at instructor table.
6. At least four empty carousel trays.
7. Overhead projector.
8. Chalk, felt-tip markers, erasers, etc.
9. Six to eight chairs randomly spaced at back and sides of room for visitors.

LESSON OUTLINE

I. Introduction to Chemical Additions (10 minutes)

A. Objectives of Lesson

1. "To introduce the topic of chemical additions to upgrade plant performance
2. To describe the importance of chemical additions in troubleshooting treatment plants."

B. Purpose of Chemical Additives to Conventional Treatment Plants

1. Improve clarification (coagulation, flocculation and sedimentation).
2. Improve disinfection (solids removal).
3. Phosphorous removal (chemical precipitation).
4. Nitrogen removal (methanol as biological carbon/energy source).
5. Other reasons
   a. Removal of colloidal solids
   b. Removal of color (carbon or coagulants)
   c. Removal of heavy metals (ppt)
   d. Removal of non-biodegradable organics (activated carbon)
   e. Sludge conditioning

C. Chemical Additions May be Used to:

1. Solve temporary operating/loading problems
2. Temporarily upgrade pending plant changes
3. Permanently upgrade performance and effluent quality

Examples: ammonia removal
phosphorous removal

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/9.1.1
Slide 179.2/9.1.1 is a blank.

Use Slide 179.2/9.1.2
Slide 179.2/9.1.2 is a word slide which reads:

"Purpose of Chemical Additives to Conventional Treatment Plants

To Improve Clarification
Through Coagulation
Phosphorous Removal"

Use Slide 179.2/9.1.3
Slide 179.2/9.1.3 is a word slide which reads:

"Chemical Additives May Be Used To

Solve Temporary Operating/
Loading Problems

LESSON OUTLINE

4. Use Slide 179.2/9.1.4 to list situations where chemicals might be used.

D. Uses of Coagulants - Hydraulic Overload

  1. Some uses can usually be planned.

  2. Examples:

    a. Excessive rainfall or drainage

    b. Clarifier outage

    c. Seasonal industrial loads

    d. Peak loading, daily or special events

E. Uses of Coagulants - Emergency Use

  1. These uses are usually unplanned and must be made immediately upon identifying a problem.

  2. Examples:

    a. Septage

    b. Industrial spills

    c. Accidental spills

KEY POINTS & INSTRUCTOR GUIDES

Temporarily Upgrade Pending Plant Modification or Expansion
Permanently Upgrade Performance and Effluent Quality"

Key Point: Chemicals can be used to achieve a variety of results.

Use Slide 179.2/9.1.4
Slide 179.2/9.1.4 is a word slide which reads:

"Situations Where Coagulants or Coagulant Aids May Be Effective

High Flow Rates in Usable Clarifiers
Control of Pollutant Dumps
Performance Upset"

Use Slide 179.2/9.1.5
Slide 179.2/9.1.5 is a word slide which reads:

"Uses of Coagulants - High Flow Rates

Excessive Rainfall or Drainage
Clarifier Outage
Seasonal Industrial Loads
Peak Loading, Daily or Special Events"

Use Slide 179.2/9.1.6
Slide 179.2/9.1.6 is a word slide which reads:

"Uses of Coagulants - Emergency Use

Control of Pollutant Dumps
Septage
Industrial Dumps
Accidental Spills
Excessive Return Flows

LESSON OUTLINE

d. Excessive loads caused by internal plant recycles

F. Uses of Coagulants - Performance Upsets

1. These uses are generally alternatives to other process controls. They must be carefully used and not habitually relied upon. These are usually crutches for temporary relief, not cures to problems.

2. Examples:

   a. Slow settling activated sludge

   b. Shock or toxic loadings

   c. Aeration difficulties

   d. Poor process control

G. Chemical additives are not always easy to use. For this reason it is important to consider

1. Some alternatives to chemicals:

   a. Flow equalization or reduction

   b. Preaeration

   c. Prechlorination

   d. Fine tune process controls

   e. Expand or modify plant

2. Alternatives should always be considered. Many may be less costly or less difficult to use.

II. Impact of Chemical Additives (10 minutes)

A. Removal Efficiencies

1. Vary by plant, process used, chemicals used, etc.

2. Generally results in substantial improvement in clarifier performance and solids removal performance.

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/9.1.7
Slide 179.2/9.1.7 is a word slide which reads:

"Uses of Coagulants - Performance Upsets

Slow Settling Activated Sludge
Shock or Toxic Loadings
Aeration Inadequacy
Poor Process Controls"

Use Slide 179.2/9.1.8
Slide 179.2/9.1.8 is a word slide which reads:

"Some Alternatives to Chemicals

Flow Reduction or Equalization
Preaeration
Prechlorination
Fine Tune Process Controls
Expand and Modify Plant"

LESSON OUTLINE

B. Removals

1. SS - increase from 50% to 80%
2. BOD - increase from 30% to 60%
3. Metals which inhibit secondary treatment
4. 80% to 95% phosphorous removal

C. Aids to Secondary Treatment

1. Activated sludge: chemicals increase settling rate in secondary clarifiers.
2. Trickling filter: chemicals enhance settling during overloaded or septic conditions.
3. Lagoons: chemicals settle solids during periods of upset.

D. Specific Results Obtained

1. Refer class to *Trainee Notebook*, pages T9.1.1 to T9.1.3.
2. Discuss *Trainee Notebook* tables as appropriate.

III. Determining Proper Chemicals and Their Doses (15 minutes)

A. Use data in tables on *Trainee Notebook* pages T9.1.1 - T9.1.3 to explain why tests must be made to determine:

1. Which polymer or chemical to use
2. pH at which additive is most effective

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/9.1.9

Slide 179.2/9.1.9 is a word slide which reads:

"Removals

SS - Increase from 50% to 80%
BOD - Increase from 30% to 60%
Metals Which Inhibit Secondary Treatment
Up to 95% of Phosphorous"

Use Slide 179.2/9.1.10

Slide 179.2/9.1.10 is a word slide which reads:

"Aids to Secondary Treatment

Activated Sludge: Increases Settling Rate in Secondary Clarifier
Trickling Filter: Enhances Settling During Overloaded or Septic Conditions
Lagoons: Settles Solids During Periods of Upset"

Use Slide 179.2/9.1.11

Slide 179.2/9.1.11 is a blank.

Key Point: Use data in tables to lead into the next session on jar testing.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
3. Dose of additive	
4. Mixing time and characteristics	
5. Resulting removals of desired component	
B. Method of Testing Chemical Additions	Refer class to *Trainee Notebook*, pages T9.1.4 and T9.1.5.
1. Jar test	Use Slide 179.2/1.9.12 Slide 179.2/1.9.12 is a photograph showing six reactor vessels in a typical jar testing experiment.
a. Outline main steps	
1) Coagulant addition and rapid mix for 15-60 seconds (100 rpm).	
2) Slow mix for 5-30 minutes (20-30 rpm).	
3) Add polymer, if used, and continue slow mix for 5-10 minutes.	
4) Settle for 10-60 minutes.	
5) Sample for removal efficiency.	
b. Discuss main limitation - what happens in the jar test may not be realistic on plant scale, but it is a start.	
2. Pilot scale testing.	
3. In-plant testing - must be done carefully but reveals best data.	
4. Have class discuss experiences with jar tests, pilot scale testing and in-plant testing.	
C. Chemicals Commonly Used in Wastewater Treatment	Refer class to page 208, *Field Manual for Performance Evaluation and Troubleshooting at Wastewater Treatment Facilities* for listing of chemicals commonly used and their characteristics.
1. Inorganic Chemicals	
a. Have been used in municipal wastewater treatment for over 75 years.	

b. Main inorganic chemicals used

   1) Lime

   2) Aluminum salts

   3) Iron salts - ferric and ferrous iron

c. Reasons for popularity

   1) They can agglomerate solids via chemical precipitation.

   2) Very efficient for removal of solids in primary and secondary sedimentation and concentration and dewatering of sludges.

d. Problems

   1) High chemical costs

   2) Material handling problems

2. Lime

   a. Removes SS, PO_4, metals, viruses, grease, pH.

   b. Acts as a sludge conditioner.

   c. May be unloaded via screen or bucket conveyers.

   d. Applied as a slurry.

   e. Dosages

      1) Lime dosage usually depends on the water's alkalinity.

      2) In most cases, dosage = 200 - 400 mg/l.

      3) Extra lime may be used to form fast settling floc.

Use Slide 179.2/9.1.13

Slide 179.2/1.9.13 is a word slide which reads:

"Lime

Quicklime - CaO
Hydrated Lime - $Ca(OH)_2$"

Refer class to pages 209-221 in *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* for descriptions and discussion of chemical feed systems.

LESSON OUTLINE

4) Metals removal will occur at pH 11.

5) At pH 11, viruses removed.

f. Problems

1) Lime dosage raises pH to 10-11. At this pH, water is unstable and calcium carbonate floc can form, encrusting the insides of piping.

2) Lime slurry is caustic.

3) Lime dust is an irritant.

3. Alum

a. Often used as a substitute for lime.

b. Used for coagulation or PO_4 removal.

c. Applied in dry or liquid form.

d. Dosage

1) Dry form = 0.5 lb alum/gal water, approximately 6%.

2) Common dose, 75-250 mg/l alum.

e. Problems

1) Aluminum adds dissolved solids to treated water - a problem is you have a TDS limit.

2) It is very difficult to dewater WAS solids if alum has been added for concentrating.

3) Alum addition requires larger scale equipment because of the additional solids generation.

KEY POINTS & INSTRUCTOR GUIDES

Up to 90% metals removal - does not include Cd, Se, Hg removal.

Key Point: The maintenance problems with lime are a major limitation to its use. Many operators report that most of their time is spent unclogging downstream pipes.

Use Slide 179.2/9.1.14
Slide 179.2/9.1.14 is a word slide which reads:

"Alum (Aluminum Sulfate)

Available in Dry and Liquid Form
Normally Requires Added Alkalinity By:
Hydrated Lime - $Ca(OH)_2$
Alkalinity - $CaCO_3$
Soda Ash - Na_2CO_3 "

Refer class to pages 209-221, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* for discussion and descriptions of chemical feed systems.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
4) Alum reacts with alkalinity. Usually need supplemental alkaline compound, such as lime or soda ash, for pH control.	Ask class for comments on their experiences
5) others?	
4. Iron Salts	Use Slide 179.2/9.1.15 Slide 179.2/9.1.15 is a word slide which reads:
a. Ferric chloride - used in dry form, liquid, crystal.	"Iron Compounds
b. Used as a coagulant, oxidant.	Liquid Ferric Chloride - $FeCl_3$ Waste Pickle Liquor - $FeCl_2$ Available from Steel Plants
c. Used to remove PO_4, SS.	Ferric Sulfate - $Fe_2(SO_4)_3$ Ferrous Sulfate - $FeSO_4$
d. Feed systems similar to those for alum liquid systems.	Normally Requires Alkalinity"
e. Dosages	
1) 45-90 mg/l is a common dose for 85-90% PO_4 removal.	
2) Liquid ferric chloride is about 35-45% $FeCl_3$.	
f. Problems	
1) Adds TDS to treated water.	
2) Iron compounds are very corrosive and must be handled with care.	
3) Contributes to discoloration of finished water.	
4) Handling problems in winter from freezing of solution.	Note: This may be caused by diluting prior to storage.
5. Other Inorganic Chemicals	Use Slide 179.2/9.1.16 Slide 179.2/9.1.16 is a word slide which reads:
a. NaOH (sodium hydroxide)	
1) Used for pH control.	"Other Inorganic Chemicals"
2) Liquid = 50%, 73% NaOH	Soda Ash - Na_2CO_3
3) Storage/feed systems - similar to liquid alum.	Liquid Caustic Soda - NaOH Carbon Dioxide - CO_2"

LESSON OUTLINE

b. CO_2

   1) Used in recarbonation - to lower the pH to a stable level

   2) CO_2 systems are designer-specific.

c. Powdered Activated Carbon

   1) Used to remove soluble organics

   2) Added as a slurry (10.7%).

   3) Feed system.

   4) Dosage depends on contact time and carbon dosage.

6. Organic Chemicals

   a. Used to remove light or fine floc that is difficult to settle. Function by "bridging" between particles.

   b. There are three main types:

      1) Anionic (-)

      2) Cationic (+)

      3) Neutral

      4) Anionic (-) is most useful in wastewater treatment due to the (+) charge on most colloids.

   c. Normal dose = 0.1-0.25 mg/l

      1) If inorganic chemicals are also used, dose = 0.25-0.5 mg/l.

      2) At 1% or greater solutions, polymer solutions are too viscious to use.

KEY POINTS & INSTRUCTOR GUIDES

Guide: There are other inorganic chemicals that may be used.

Refer class to page 171, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* for discussion of activated carbon systems.

Use Slide 179.2/9.1.17

Slide 179.2/9.1.17 is a word slide which reads:

"Polymers - Polyelectrolytes"

Come in Dry or Liquid Form
Plus Charge - Cationic
Negative Charge - Anionic
No Charge - Non-ionic"

LESSON OUTLINE

d. Use of Polymers - Factors to be Considered

   1. Size, density and charge of colloids to be coagulated.
   2. pH
   3. Coagulants used
   4. Feeding and mixing
   5. Jar testing and plant scale testing is a must!!

IV. Applying Chemicals (15 minutes)

   A. Factors in Applying Chemicals

      1. Chemical storage facilities
      2. Mixing equipment
      3. Dosing equipment
      4. Point of introduction
      5. Distribution piping
      6. Protected storage and working areas
      7. Laboratory
      8. Capable staff

   B. Chemical Storage Facilities

      1. Volume and type depend upon type of chemical, amount, supply and shipping arrangements.
      2. Chemicals in solution:

         a. Simplify mixing and dosing.
         b. Often corrosive - require tankage protected from corrosion.

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/9.1.18
Slide 179.2/9.1.18 is a word slide which reads:

"Use of Polymers - Factors to Be Considered

Size, Density and Charge of Colloids to be Coagulated
pH
Coagulants Used
Feeding and Mixing
Jar Testing and Plant Scale Testing is a Must!"

Recommend plant scale in lieu of only bench-scale testing.

Use Slide 179.2/9.1.19
Slide 179.2/9.1.19 is a word slide which reads:

"Factors in Applying Chemicals"

Chemical Storage Facilities
Mixing Equipment
Dosing Equipment
Point of Distribution
Distribution Piping
Protected Storage and Working Areas
Laboratory
Capable Staff"

Use this slide as an introduction to the section. Keep slide on screen while discussing material.

Discuss each factor with class.

LESSON OUTLINE

3. Dry Chemicals
   a. Lower shipping costs
   b. More costly to mix and handle

C. Mixing

1. Needed for dry chemicals.
2. Should be sufficient for 1 - 3 days supply
3. Without adequate mixing, polyelectrolytes form viscous masses and non-uniform solution.
4. Must use adequate energy for mixing.
5. Undermixing:
   a. Results in uneven dosing
   b. Reduces efficiency of solids removal
   c. Requires unnecessarily high coagulant doses.
6. Overmixing:
   a. Disperses newly formed floc
   b. Increases flocculation period
   c. Ruptures existing wastewater solids - thus bringing less efficient removal

D. Dosing

1. Can be simple or elaborate, depending on situation.
2. Powdered chemicals - small doses can be sprinkled over tank or inlet channel.
3. Solution feeders - example
   Rubber tube siphon and pinch clamp
4. Dry feeders - can provide uniform feed rate at higher dosages.

KEY POINTS & INSTRUCTOR GUIDES

Refer class to pages 229-234, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* for discussion of mixing and flocculation.

LESSON OUTLINE

5. Solution feeders - chemically resistant
    a. Adjustable dosage control
    b. Sufficient head pressure if feeds into tank bottom or closed conduit.

E. Point of Introduction

1. Into any point of high mixing energy, such as open channel, pump inlet, eye of aerator, flash mix chamber.
2. Monitor floc formation and coagulant use.

F. Distribution Piping

1. Allows for optional introduction points in fixed systems.
2. Use screens to prevent trash or lumps from flowing through.
3. Should be corrosion resistant.
4. Provide for cleanout and flushing.

G. Protected Areas - necessary in many cases to provide protection from weather.

H. Laboratory - needed for jar testing, monitoring of effluent quality, etc.

I. Capable Staff - needed for added functions created by chemical additions, including:

1. Monitoring and process control.
2. Sampling and jar testing.
3. Cleanup, maintenance and sludge handling.

V. Consequences of Chemical Additives (10 minutes)

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/9.1.20

Slide 179.2/9.1.20 is a schematic diagram showing possible points of coagulant application as prior to the primary clarifier, prior to to the aeration basin, into the aeration basin, prior to the final clarifier, following the final clarifier.

Key Point: Stress that chemical additions have both advantages and disadvantages that need to be considered.

LESSON OUTLINE

A. Advantages

1. Relieve severely stressed secondary treatment systems.
2. Increase removal efficiencies.
3. "Buy time" for plant until major modifications can be made.
4. Handle peak loadings or upsets.

B. Discuss the following disadvantages of chemical additives

1. Cost - chemicals, equipment, energy, sludge disposal.
2. Larger volumes of sludge to handle.
3. Requires more process control and monitoring.
4. Requires more sampling and testing.
5. Additional maintenance
6. Additional safety hazard.

C. Some problems with Chemical Addition Systems

1. Maintenance
   a. Maintenance of pH monitor for chemical feed.

      When an acid neutralization step is involved in the process, automated pH control may be used. The main problem associated with this type of control is to maintain accurate pH measurements. The pH system should

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/9.1.21
Slide 179.2/9.1.21 is a word slide which reads:

"Coagulation Benefits

1. More Oxygen Demand Removal
2. Precipitation of P, Hg, Pb, etc.
3. Pretreatment, Run Extension, or Upgrading Performance of Other Unit Operations
4. Improves Dewatering, Disposal and Effluent Quality"

Use Slide 179.2/9.1.22
Slide 179.2/9.1.22 is a word slide which reads:

"Disadvantages to Chemical Additives

Cost - Chemicals, Equipment, Energy, Sludge Disposal
Larger Volumes of Sludge to Handle
Requires More Process Control and Monitoring
Requires More Sampling and Testing
Additional Maintenance
Additional Safety Hazard"

Note: All slides were taken at the Rosemount Advanced Waste Treatment Plant, Rosemont, Minnesota, 1975.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
be checked a minimum of once each day until it proves to be reliable for longer periods. Electrode cleaning may be required on a daily basis.	
1) Debris from pH control box	Use Slide 179.2/9.1.23 Slide 179.2/9.1.23 is a photograph which shows an operator performing maintenance on an automatic pH control system.
2) Cleaning electrodes with dilute HCL.	Use Slide 179.2/9.1.24 Slide 179.2/9.1.24 is a photograph which shows the electrodes in a pH control box which require daily cleaning to remove crusted lime deposits.
b. Monitoring chemical feed Operator checking drawdown on a 5 gallon carboy installed to calibrate pumps feeding ferric chloride solution. Liquid ferric chloride storage tank is in background.	Use Slide 179.2/9.1.25 Slide 179.2/9.1.25 is a photograph which shows the operator checking the draw-down on a 5 gallon carboy installed to calibrate pumps feeding ferric chloride solution. Liquid ferric chloride storage tank is shown in background.
c. Lime Feed Maintenance 1) Lime feed pumps with check valves exposed - lime deposits.	Use Slide 179.2/9.1.26 Slide 179.2/9.1.26 is a photograph which shows the heavy lime deposits on check valves and line from the lime feed pumps. Example of a facet of chemical additions that requires constant maintenance.
2) Check valve prior to cleaning - valves do not seat because of small pebbles and lime deposits.	Use Slide 179.2/9.1.27 Slide 179.2/9.1.27 is a photograph of the check valve shown in the previous slide before cleaning showing large lime deposits and encrustations.
3) Clean check valve	Use Slide 179.2/9.1.28 Slide 179.2/9.1.28 is a photograph of the check valve shown in the previous slide after cleaning.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Safety hazards increase when chemicals are introduced at a plant. Precautions must be taken.	
a. Eye wash near chemical feed pumps	Use Slide 179.2/9.1.29 Slide 179.2/9.1.29 is a photograph which shows an eye wash located near the chemical feed pumps - an important safety precaution.
b. Shower near chemical feed pumps.	Use Slide 179.2/9.1.30 Slide 179.2/9.1.30 is a photograph which shows an emergency shower located near the chemical feed pumps.
c. Likewise, precautions must be taken against the possibility of dangerous fumes.	Use Slide 179.2/9.1.31 Slide 179.2/9.1.31 is a photograph which shows emergency breathing equipment located throughout the plant.
D. Other Chemicals Plant operators have been tempted by salesmen making claims for other chemicals as "miracle" ingredients to solve problems at treatment plants. Such chemicals include: 1. Masking agents - to mask plant odors. 2. Enzymes - to "improve" biological treatment. 3. There is limited evidence as to the value of these chemicals and troubleshooters should recommend their use cautiously.	Use Slide 179.2/9.1.32 Slide 179.2/9.1.32 is a blank.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 9: Chemical Additions

Lesson 1: Using Chemicals to Upgrade Treatment Plants

Trainee Notebook Contents

Effect of Chemical Treatment on Primary Clarifier Performance T9.1.1

Polyelectrolyte Addition to Primary Clarifiers T9.1.2

Lime Addition to Primary Clarifiers T9.1.2

Effect of Chemical Treatment on Secondary Clarifier Performance T9.1.3

Determining Chemical Dosage: Jar Test T9.1.4

Typical Jar Test Results T9.1.5

EFFECT OF CHEMICAL TREATMENT ON PRIMARY CLARIFIER PERFORMANCE

Type and Amount of Chemical Added	Performance Preceding Chemical Treatment				Weight Ratio of WAS/PS[1]	Performance After Chemical Treatment				Weight Ratio of WAS/PS[1]
	SS Removed		BOD Removed			SS Removed		BOD Removed		
	mg/l	percent	mg/l	percent		mg/l	percent	mg/l	percent	
Purifloc – A21 (0.95 mg/l)	13	12	28	26	0.61	75	65	46	48	0.31
DOW – SA 1193 (0.2 mg/l)	13	12	28	26	0.61	72	55	36	37	0.41
Purifloc – A21 (1 mg/l)	157	43	82	23	–	281	76	127	33	–
Purifloc – A21 (0.75 mg/l)	26	18	–	–	–	69	52	–	–	–
Purifloc – A21 (0.89 mg/l)	113	43	50	22	–	159	60	87	37	–
DOW – SA1193 (0.25 mg/l)	120	47	–	–	0.8	151	61	–	–	0.46
Purifloc – A21 (1 mg/l)	107	47	135	37	–	169	62	154	46	–
FeCl$_2$ + NaOH + Purifloc - A23 (0.3 mg/l)	230	82	111	31	–	379	79	74	39	–
FeCl$_2$ + NaOH + Purifloc – A23 (0.3 mg/l)	104	49.7	83	43.8	–	173	76.8	105	57.8	–
Purifloc – A21 (1 mg/l)	–	–	–	–	0.79	–	–	–	–	0.28
Purifloc – A23 (0.25 mg/l)	52	31	47	31	1.44	80	51	58	46.4	0.67
FeCl$_3$ + Purifloc – A23	93	33	53	34	–	196	74	102	61	–
FeCl$_3$ + Purifloc -- A23	93	33	53	34	–	213	68	97	53	–
Purifloc – A21 (0.74 mg/l)	–	50	–	36	–	–	63	–	45	–
Purifloc – A21M (1.14 mg/l)	–	43	–	–	–	–	63	–	–	–
FeCl$_3$ (20 mg/l) + Purifloc – A23 (0.3 mg/l)	1	1.3	–	–	–	38	24.4	–	–	–
FeCl$_3$(35 mg/l Fe^{3+}) + Purifloc – A23 (0.5 mg/l)	–	–	–	–	–	323	80	249	61	–
FeCl$_3$ (15–18 mg/l Fe^{3+}) + Purifloc – A23 (0.5 mg/l)	–	35.5	–	19.1	–	–	63.6	–	54.4	–
FeCl$_3$ (10 mg/l Fe^{3+}) + Purifloc – A23 (0.5 mg/l)	–	–	–	–	–	177	74.5	–	–	–
FeCl$_3$ (20-25 mg/l Fe^{3+}) + Purifloc – A23 (0.4 mg/l)	–	–	–	–	–	41	74.0	115	57.4	–
FeCl$_3$(22 mg/l Fe^{3+}) + Purifloc – A23 (0.5 mg/l)	–	–	–	–	–	61.7	84	226	38	–
Alum (15–20 mg/l A1^{3+}) + Purifloc – A23 (0.5 mg/l)	–	–	–	–	–	134.8	70	423.9	32	–
Alum (90 mg/l) + Polyelectrolyte (0.4 mg/l)	–	–	–	–	–	157	84	66	61.1	–
Alum (110 mg/l) + Polyelectrolyte (0.35 mg/l)	–	–	–	–	–	204	74	126	71	–

[1] WAS – Waste activated sludge
PS – Primary sludge

Source: *Design Manual for Upgrading Existing Wastewater Treatment Plants*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (1974).

T9.1.1

POLYELECTROLYTE ADDITION TO PRIMARY CLARIFIERS

Treatment Process	Coagulant	Dose	Primary Clarifier				Total Plant			
			Percent Removal Before Poly-electrolyte Addition		Percent Removal After Poly-electrolyte Addition		Percent Removal Before Poly-electrolyte Addition		Percent Removal After Poly-electrolyte Addition	
		mg/l	BOD	SS	BOD	SS	BOD	SS	BOD	SS
Activated Sludge	Purifloc A-21	1	26	–	48	–	83	–	90	–
Trickling Filter	Purifloc A-21	1	23	43	33	76	79	72	85	84
Activated Sludge	Purifloc A-23	0.21	31	31	46	51	79	85	83	89

LIME ADDITION TO PRIMARY CLARIFIERS

Location	Lime Added	Percent Removal in Primary Before Lime Addition		Percent Removal in Primary After Lime Addition		Remarks
	mg/l CaO	BOD	SS	BOD	SS	
Duluth, Minnesota	75	50	70	60	75	–
	125	55	70	75	90	–
Rochester, New York	100	–	–	50	80-90	Jar tests
Lebanon, Ohio	145	–	–	66	74	Pilot plant
Richmond Hill, Ontario	175	21	37	71	77	Full-scale plant
Central Contra Costa, Calif.	378	46	71	74	79	Full-scale test
	303	37	71	69	76	Full-scale test

Source: *Design Manual for Upgrading of Existing Wastewater Treatment Plants*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (1974)

EFFECT OF CHEMICAL TREATMENT ON SECONDARY CLARIFIER PERFORMANCE

Location	Type of Plant	Location of Chemical Addition	Chemical and Dosage	Effluent BOD$_5$ (or COD) Before Chemical Addition mg/l	Effluent SS Before Chemical Addition mg/l	Effluent BOD$_5$ (or COD) After Chemical Addition mg/l	Effluent SS After Chemical Addition mg/l	Total Phos Removal percent
Richardson, Texas	Trickling filter std. rate	Before final settling	Al/P Mole Dosage 1.6/1	20	15	<5	<7	95
Chapel Hill, North Carolina	Trickling filter high rate	Before final settling	Al/P Mole Dosage 1.6/1	14	64	15	34	82
Pennsylvania State	Conventional activated sludge	Aerator effluent	Al/P wt. Ratio 3/1	13	26	9	22	86
Cincinnati, Ohio	Activated sludge (100 gpd pilot)	Aerator	10 mg/l Al^{3+}	(89%)[1]	(95%)[1]	(92%)[1]	(96%)[1]	94
Lebanon, Ohio	Activated sludge (0.11 mgd pilot)	Final clarifier	Add lime to raise pH=9.4-10.9	–	43.5	--	16.5	--
Minneapolis, Minnesota	Trickling filter low rate	Before final settling	720 mg/l $Ca(OH)_2$	83	–	27	--	86
Madison, Wisconsin	--	Before final settling	200 mg/l Alum	8-29	–	1.8–2.9	–	98.7
University Park, Pennsylvania	Trickling filter	Before final settling	160 mg/l Alum	18	31	6	19	96.4
			46 mg/l $Na_2Al_2O_4$	61	95	23	8	93.4
Bloomington, Illinois	Activated sludge	Aerator	33.9 mg/l Fe^{3+} +0.7 mg/l Purifloc A23	8.8	12.7	5.0	8.6	--
	Trickling filter	Before final settling	25-30 mg/l Fe^{3+} +0.5 mg/l Purifloc – A23	13.0	19.6	3.3	16.0	--
Blue Plains,[2] Washington, D.C.	Modified Activated sludge	Before final settling	26 mg/l Alum	47	48	40	43	--
			50 mg/l Alum	38	39	27	36	--
			60 mg/l Alum	68	53	25	36	--
			80 mg/l Alum	46	41	41	31	--
			89 mg/l Alum	50	57	30	31	--
Sandusky, Ohio	Conventional activated sludge	Aerator	50 mg/l Alum	9	24	2	15	80
Michigan City, Indiana	Conventional activated sludge	Aerator	60 mg/l Alum	13	19	9	7	92.2
Guelph, Ontario	Conventional activated sludge	Aerator	100 mg/l Alum	26	38	14	22	87
Palmetto, Florida	Trickling filter	Before final settling	45 mg/l Alum	–	30-40	--	10	--

[1] Percent removal.

[2] Data are monthly average.

Source: *Design Manual for Upgrading Existing Wastewater Treatment Plants*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (1974).

T9.1.3

Determining Chemical Dosage: Jar Test

For any given treatment system there are a large number of coagulants and combination of coagulants and coagulant aids (polymers) that can be used to obtain the required effluent quality. The difficult task is to identify those combinations that are best in terms of economics and other considerations. Other considerations being: sludge volume and dewatering characteristics, chemical delivery times and storage requirements, hazards associated with some materials, and so forth.

Chemical dosages required can be estimated in the laboratory using standard jar testing apparatus. The jar test procedure used should be designed to simulate, as closely as possible, the chemical addition and mixing conditions found in the full scale process. The test will generally follow the scheme outlined below:

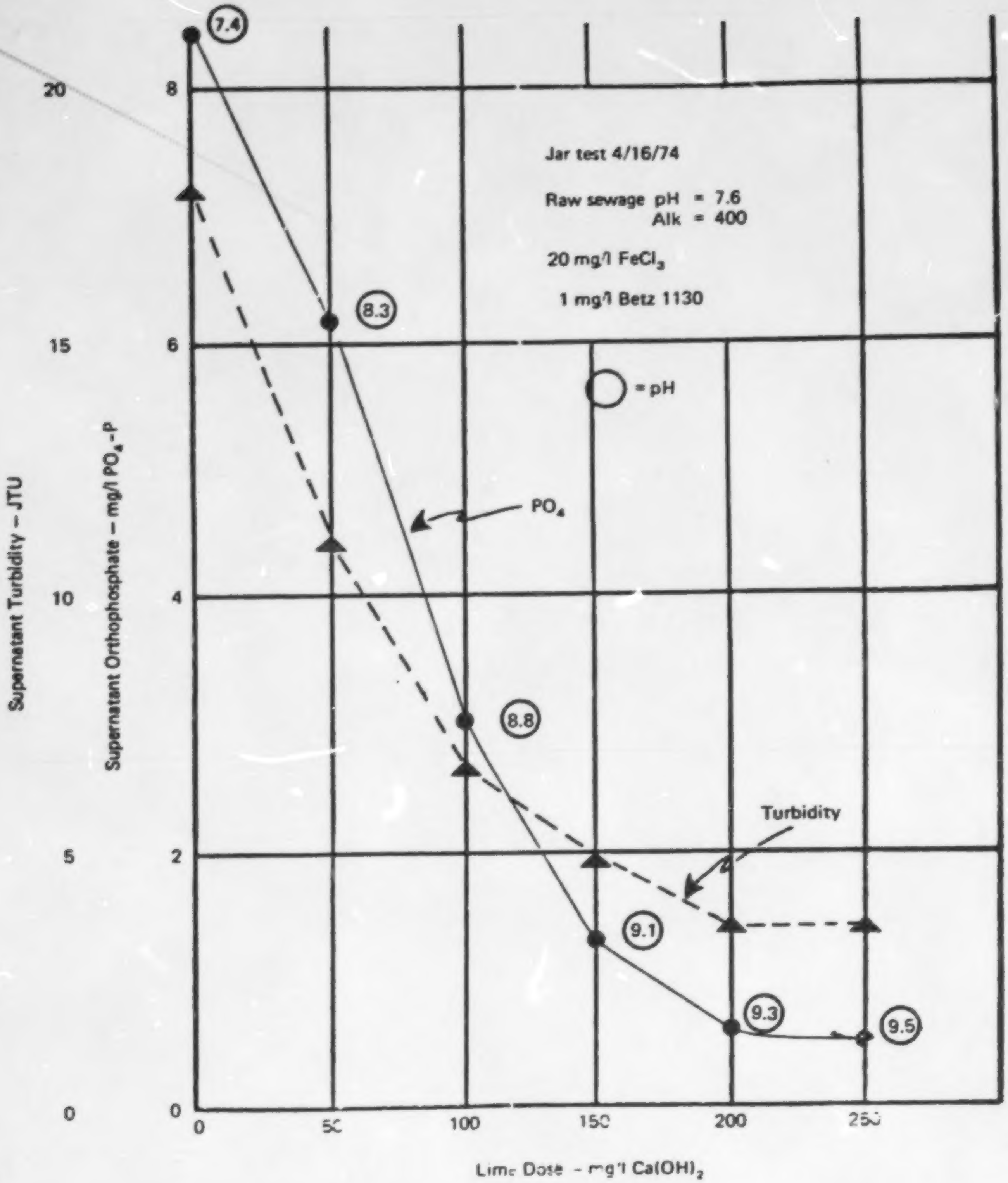
1. Coagulant addition and rapid mix for 15-60 sec. (100 rpm)
2. Slow mix for 5-30 min.(20-30 rpm)
3. Add polymer and continue slow mix for 5-10 min.
4. Settle 10-60 min.
5. Sample for analyses.

The results of a typical jar test are presented in Figure 1, page T9.1.5. The test was conducted to observe the effect of lime dose (pH) on phosphorous and turbidity removals when used with ferric chloride and polymer. The test procedure was:

1. Fill 6 jars with 1 liter raw sewage each.
2. Add lime and rapid mix for 5 minutes at 100 rpm.
3. Add ferric chloride and rapid mix for 1 minute at 100 rpm.
4. Mix at 50 rpm for 1 minute.
5. Add polymer and mix for 1 minute at 50 rpm.
6. Slow mix for 15 minutes at 25 rpm.
7. Settle for 25 minutes.
8. Sample supernatant.

The raw sewage characteristics were:

pH = 7.6
Alkalinity = 400 mg/l as $CaCO_3$
PO_4-P = 10.8 mg/l



TYPICAL JAR TEST RESULTS

T9.1.5

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 9: Chemical Additions

Lesson 2: Troubleshooting Plants with Chemical Additions

Lesson 2 of 2 Recommended Time: 60 minutes

Purpose: This lesson discusses application of the *Process of Troubleshooting* to plants which use chemical treatment. The lesson is loosely structured to permit a maximum of class participation in an extended question and answer period.

Trainee Entry Level Behavior: Trainees should have achieved the learning objectives specified for Unit 9, Lesson 1 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee should be able to:

1. List the factors which should be considered in evaluating chemical treatment systems and in making the decision to use chemicals to upgrade plant performance.
2. List and identify trouble indicators in chemical addition.
3. List probable causes to trouble indicators in chemical addition.
4. Describe troubleshooting checks to determine the nature of chemical addition problems.
5. List possible solutions to common chemical addition problems.

Instructional Approach: Illustrated lecture with questions and open discussion.

Lesson Schedule: The 60 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 2 minutes	Basis for Troubleshooting Chemical Additions
2 - 5 minutes	Process of Troubleshooting
5 - 15 minutes	Troubleshooting Plants with Chemical Additions
15 - 60 minutes	Questions and Discussion - Class Specific

Trainee Materials Used in Lesson:

1. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*,
2. *Trainee Notebook*, page T9.2.1, "References."

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 9.2.1 - 9.2.8, Unit 9, Lesson 2.
2. Slides 179.2/9.2.1 - 179.2/9.2.9.

Instructor Materials Recommended for Development: None

Additional Instructor References: As specified for Unit 9, Lesson 1.

Classroom Set-Up: As specified in Unit 9, Lesson 1.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Basis for Troubleshooting Plants With Chemical Additions (2 minutes)	Use Slide 179.2/9.2.1 Slide 179.2/9.2.1 is a blank
A. As chemical additions become more widely used, troubleshooters will have to begin to cope with plants using chemical additions.	
1. Particularly in small plants, efficiency of operation may decrease once the plant is past the experimental stage.	
B. Don't attempt to troubleshoot in such situations unless you know what you are doing.	Key Point: Troubleshooters must be experienced in chemical additions or may have to seek outside help.
C. Make sure you have proper information and background on plant.	
1. Know why chemicals are being used in the first place.	
2. Know what performance is expected.	
3. Know under what conditions chemicals are to be applied.	
II. Because of the complexity of the chemical reactions involved, and the cause/effect of chemical reactions to changing parameters, the use of a systematic Process of Troubleshooting is a must (3 minutes)	Key Point: Process of Troubleshooting is valuable in dealing with problems of chemical additions.
Particularly important elements of the Process of Troubleshooting are:	
A. Reviewing plant information (1b)	Numbers in () refer to elements on the chart: The Process of Troubleshooting. Instructor should refer to troubleshooting chart in the *Trainee Notebook*, page T2.2.8.
B. Listening to others and observing (1c)	
C. Analyzing and testing (1e)	
D. Formulating prioritized alternatives (2d)	
E. Confirming opinions (2e)	
F. Observing results and effects (4)	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
G. Monitoring results (5b)	
H. Documentation and follow-up (5c)	
III. Troubleshooting Plants With Chemical Addition (10 minutes)	Key Point: Troubleshooters may need outside help with this!
A. Summary of Troubleshooter Actions	Use Slide 179.2/9.2.2 Slide 179.2/9.2.2 is a word slide which reads:
1. Know expected plant and unit performance.	"Troubleshooting Chemical Additions
2. Observe to collect data (visual, analytical, etc.).	Know Expected Plant Performance Observe to Collect Data
3. Perform tests and analyses.	Perform Tests and Analyses
4. Select possible alternatives.	Select Possible Alternatives
5. Monitor correction procedure.	Monitor Correction Procedure Long Term Follow-Up is Important"
6. Long-term follow-up is important!	
B. Trouble Indicators are Varied	
1. Know expected plant performance	Use Slide 179.2/9.2.3 Slide 179.2/9.2.3 is a word slide which reads:
a. Removal characteristics	
b. pH requirements for chemical reaction	"Know Expected Plant Performance
c. Proper performance of all equipment involved	Removal Characteristics pH Requirements for Chemical Reaction Proper Performance of All Equipment Involved
d. Sludge characteristics	Sludge Characteristics"
	Key Point: This is an important step in the troubleshooting Process
2. Trouble indicators	Use Slide 179.2/9.2.4 Slide 179.2/9.2.4 is a word slide which reads:
a. Floating and gaseous sludge in primary clarifiers	

LESSON OUTLINE

b. Poor sludge settling characteristics

c. Poor sludge dewatering characteristics

d. Poor removals of solids or phosphorous.

3. Observations - For Troubleshooting Chemical Additions

   a. Dosing sequence of chemicals

   b. Energy in mixing

   c. Flocculation energy

   d. Sludge behavior

4. Tests and Analyses for Chemical Additions

   a. Quantity of chemicals used

   b. pH, alkalinity

   c. Jar tests

   d. Effluent quality, solids, BOD, phosphorous

5. Possible Alternative Corrections

   a. Change dosage of coagulants and alkalinity

   b. Change points of introduction of chemicals

   c. Assure sufficient rapid mix energy

KEY POINTS &
INSTRUCTOR GUIDE

"Trouble Indicators

Floating and Gaseous Sludge in Primary Clarifiers
Poor Sludge Settling Characteristics
Poor Sludge Dewatering Characteristics
Poor Removal of Solids of Phosphorous"

Use Slide 179.2/9.2.5
Slide 179.2/9.2.5 is a word slide which reads:

"Observations for Troubleshooting Chemical Additions

Dosing Sequence of Chemicals
Energy in Mixing
Flocculation Energy
Sludge Behavior"

Use Slide 179.2/9.2.6
Slide 179.2/9.2.6 is a word slide which reads:

"Tests and Analyses for Chemical Additions

Quantity of Chemicals Used
pH, Alkalinity
Jar Tests
Effluent Quality, Solids, BOD, Phosphorous"

Use Slide 179.2/9.2.7
Slide 179.2/9.2.7 is a word slide which reads:

"Possible Alternative Corrections

Change Dosage of Coagulants and Alkalinity
Change Points of Introduction of Chemicals

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
d. Adjust dosage in line with flow and concentration of inflow	Assure Sufficient Rapid Mix Energy Adjust Dosage in Line With Flow and Concentration of Inflow"
	Guide: These possible troubleshooter recommendations all require considerable knowledge and analyses.
IV. Lesson Summary - Chemical Additions	Use Slide 179.2/9.2.8 Slide 179.2/9.2.8 is a word slide which reads:
A. Chemicals upgrade plant performance.	
B. Chemicals require careful analyses.	"Lesson Summary - Chemical Additions
C. Chemicals add to the cost of operation and create secondary effects in the plant.	Chemicals Upgrade Plant Performance Chemicals Require Careful Analyses Chemicals Add to Cost of Operation and Create Secondary Effects in Plant Chemical are More Difficult to Troubleshoot Than Conventional Operations"
D. Chemicals are more difficult to troubleshoot than conventional operations.	
	Guide: Keep this slide on the screen while summarizing the topic.
V. Questions and Disucssion (45 minutes)	Use Slide 179.2/9.2.9 Slide 179.2/9.2.9 is a blank.
A. Close this lesson with an open discussion and trainee questions/exchange concerning chemical additions and advanced waste treatment.	Class should be permitted to direct the discussion of chemicals and advanced waste treatment to specific problems of interest to the class.
B. Discuss "Common design shortcomings and and ways to compensate"	Refer class to page 226, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities.*
1. High effluent TDS	
a. Problem	

Use of iron or aluminum salts adds significant quantities of dissolved solids - such as sulfate and chloride to the treated water.

b. Solution

If possible use lime instead of alum or ferric chloride as the coagulant.

2. Inadequate monitoring equipment

a. Problem

Inadequate equipment for monitoring coagulation process installed.

b. Solution

Run frequent jar tests; install continuous turbidity monitoring equipment on effluent from clarifiers or filters.

3. MgOH Precipitate

a. Problem

Lime added to hard waters containing magnesium may form MgOH which is a gelatinous precipitate that may adversely affect sludge dewatering.

b. Solution

Reduce operating pH to 10.5 or less.

4. Insufficient feed flexibility

a. Problem

Lack of flexibility in points at which chemicals can be added to wastewater processes.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

- b. Solution

  Run hoses from chemical feeders to desired points of chemical addition until suitable piping can be installed.

5. Dry feeders don't feed

   a. Problem

   Dry feed chemicals deposit in feeder.

   b. Solution

   Provide mechanical mixers for dissolving solids and maintaining them in suspension prior to delivery to feeder.

6. Chemicals corrosion

   a. Problem

   Corrosive properties of some chemicals.

   b. Solution

   Use proper materials for transport and handling of chemicals.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 9: Chemical Additions

Lesson 2: Troubleshooting Plants with Chemical Additions

Trainee Notebook Contents

References T9.2.1

REFERENCES

1. *Carbon Adsorption*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (1973).

2. Metcalf and Eddy, Inc., *Wastewater Engineering Treatment Disposal Reuse*, McGraw-Hill Book Co., New York (2nd edition, 1979).

3. *Nitrogen Control*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (1975).

4. *Operation of Wastewater Treatment Plants, MOP 11*, Water Pollution Control Federation, Washington, D.C. (1976).

5. *Phosphorous Removal*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (1971).

6. *Sulfide Control in Sanitary Sewerage Systems*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (1974).

7. *Suspended Solids Removal*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (1975).

8. *Upgrading Existing Wastewater Treatment Facilities*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (1974).

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 10: Management Behavior

Unit 10 of 15 Units of Instruction

Lessons in Unit: 3 Recommended Time: 3 1/3 hours

Instructor Overview of the Unit

Rationale for the Unit: Many problems causing poor wastewater treatment facility performance are caused by inadequate management of the facility. What on the surface may appear to be a purely technical problem may actually derive from a failure or a deficiency in the management structure and programs at the facility. Most O & M problems eventually boil down to people problems. The majority of persons involved in wastewater treatment facility evaluation and troubleshooting functions are technically trained and tend to focus on technical solutions to O & M problems. This unit forces the trainee to consider management as an alternative cause of O & M problems and develops concepts which the trainee can use in evaluating management related problem causes and recommending appropriate corrective actions.

Trainee Entry Level Behavior: The trainee should have completed Unit of Instruction 2: *Elements of Troubleshooting* before beginning this unit.

Trainee Learning Objectives: At the conclusion of this Unit of Instruction, the trainee will be able to:

1. By solving a case history problem, identify that technical problems may be caused by a deficiency in management, supervision or administration and that the solution to the problem is correction of management deficiencies.

2. From memory, describe why good management is essential to good wastewater treatment plant operations and maintenance.

3. From memory, describe how the troubleshooter can assist in solving management related O & M problems and explain when it is appropriate for the troubleshooter to address management problems.

4. From memory, describe how the troubleshooter may identify management related problems as the possible cause of O & M deficiencies at wastewater treatment plants by listing the observations and other indicators of potential management problems at treatment plants.

5. From memory, define and contrast the terms *management skills* and *management systems* and describe the troubleshooter's role in dealing with problems in each area.

6. Explain the importance of maintenance management to achieving overall treatment goals.

7. Using references, list the components of a maintenance management system, explain the importance of each component and describe how the troubleshooter would evaluate a maintenance management system.

8. From memory, lsit the major factors external to the treatment plant that may affect plant management and explain the significance of each factor.

9. From memory, list and describe the five functions of management and explain why each is important to wastewater treatment plant operations.

10. Using the management audit included in the *Trainee Notebook*, explain how the troubleshooter can assist a wastewater treatment facility manager evaluate the plant's management programs.

11. Demonstrate an ability to analyze a management related problem and advise the wastewater facility manager on management related issues by analyzing two case history problems.

Sequencing and Pre-Course Preparation for the Unit: This unit of Instruction is presented as three lessons.

Lesson 1: Management/Administration and Treatment Plant Operations

Recommended Time: 60 minutes

Purpose: Internal management and administrative procedures can have a significant impact on wastewater treatment facility performance. This lesson introduces the subject of management and relates it to wastewater treatment facility operations and performance. It guides the trainee toward determining when and how the troubleshooter will be able to evaluate and assist in resolution of management related problems at wastewater treatment facilities.

Training Facilities:

1. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees.
2. Instructor table with lectern.
3. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.
4. Easel with pad.
5. 35mm carousel projector with remote control changer at instructor table.
6. At least four empty carousel trays.
7. Overhead projector.
8. Chalk, felt-tip markers, erasers, etc.
9. Six to eight chairs randomly spaced at back and sides of room for visitors.

Pre-Course Preparation:

1. Trainee Texts:
   a. Order and have available at each trainee seating position *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA 430/9-78-001, Municipal Operations Branch, U. S. Environmental Protection Agency, Washington, D.C. (January, 1978).
2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, pages T10.1.1 - T10.1.2, "Problem Statement and Answer Sheets."
3. Trainee Handout materials

   Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plans.

   a. None required for Lesson 1.

Instructional Approach: Trainee problem solving, class discussion and illustrated lecture.

Lesson 2: Troubleshooting Management Systems

Recommended Time: 90 minutes

Purpose: This lesson differentiates between management skills and management systems. The troubleshooter's role in evaluating management systems and recommending corrective action programs is discussed. Maintenance management systems are discussed in detail.

Training Facilities: As specified in Lesson 1.

Pre-Course Preparation:

1. Trainee Texts:
   a. As specified in Lesson 1.
2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, pages T10.2.1 - T10.2.25, "Maintenance Management."
3. Trainee Handout Materials

   Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plans.

   a. None required for Lesson 2.

Instructional Approach: Illustrated lecture with class discussion.

Lesson 3: Managerial Functions

Recommended Time: 50 minutes

Purpose: The wastewater treatment facility manager performs five basic functions: planning, organizing, staffing, directing and controlling. This lesson briefly defines each managerial function and provides the trainee a "management audit" form which can be used by the wastewater treatment managers as a self-appraisal of their management programs. Case history problems are analyzed to emphasize the importance of management evaluation to overall wastewater treatment facility troubleshooting.

Training Facilities: As specified for Lesson 1.

Pre-Course Preparation:

1. Trainee Texts:

   a. As specified for Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   1. *Trainee Notebook*, page T10.3.1, "The Managerial Functions."
   2. *Trainee Notebook*, pages T10.3.2 - T10.3.3, "The Management Audit."
   3. *Trainee Notebook*, pages T10.3.4 - T10.3.9, "Management Audit Checklist."
   4. *Trainee Notebook*, page T10.3.10, "Case History Problem 1."
   5. *Trainee Notebook*, page T10.3.11, "Case History Problem 2."
   6. *Trainee Notebook*, page T10.3.12, "References."

3. Trainee Handout materials

   Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plans.

   a. None required for Lesson 3.

Instructional Approach: Illustrated lecture, problem solving and class discussion.

Presentation Options for the Course Director: It has been the experience of the course developers that the unit of instruction on management behavior creates more discussion and interchange between trainees than any other unit in the course. Almost without exception, all trainees who take the course have encountered one or more situations where management related problems had to be addressed in a plant evaluation or troubleshooting assignment. The majority of trainees have lacked the experience, knowledge or background to tackle such problems. The unit on management behavior has proven to be very valuable to trainees and the course developers recommend that it be included in its entirety in all courses on *Troubleshooting O & M Problems in Wastewater Treatment Facilities*.

The 200 minute unit can be condensed to 150 minutes by deleting the two problems included in lesson 3 of the unit. The course developers have done so in several presentations of the course but recommend against doing this. Another option for shortening this unit is to restrict the detailed discussion of maintenance management systems in lesson 2 to an overview introduction to the *Trainee Notebook* materials. However, the course developers find that trainees benefit greatly from the interexchange of information when the maintenance management system materials are discussed.

Rather than shortening this unit of instruction, the course developers prefer to lengthen the unit to four full hours to permit a maximum of trainee interaction on management related problems which they have encountered in the field. Specific areas where expansion is suggested are in lesson 2 on management systems. Trainees may be given more time for discussion about management systems such as training, staffing, organization, communications, safety, planning, etc.

Summary of Unit of Instruction 10: Management Behavior

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
1. Management/ Administration and Treatment Plant Operations	1. Identify management deficiencies as a possible cause of poor plant performance	1. Management defects which can cause an O & M related problem	1. Trainee problem solving and discussion	1. *Trainee Notebook*, pages T10.1.1 - T10.1.2
60 minutes	2. Describe the relationship of management to O & M	2. Management's role in treatment plant operations	2. Illustrated lecture with discussion	2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pp. 295-314.
	3. Identify the troubleshooter's role in solving management related problems	3. The troubleshooters role in identifying management related problems	3. Recording information on chalkboard	3. *Instructor Notebook*, pages 10.1.1 - 10.1.10
				4. Slides 179.2/10.1.1-179.2/10.1.3
2. Troubleshooting Management Systems	1. Identify indicators of management related problems	1. Indicators of management problems	1. Illustrated lecture with trainee discussion	1. *Trainee Notebook*, pages T10.2.1 - T10.2.25
90 minutes	2. Define, compare and contrast management skills and management systems	2. Management skills and management systems	2. Frequent reference to *Trainee Notebook* materials	2. *Instructor Notebook*, pages 10.2.1 - 10.2.12

Summary of Unit of Instruction 10: Management Behavior (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
	3. Identify the components of a maintenance management system	3. Maintenance management system	3. Recording information on chalkboard	3. Slides 179.2/10.2.1 - 179.2/10.2.13
	4. Develop evaluation criteria for maintenance management systems	4. Maintenance management system evaluation checklist		
	5. Identify external factors which affect treatment plant management	5. External factors affecting treatment plant management		
3. Managerial Functions 50 minutes	1. Define management functions	1. Management functions	1. Illustrated lecture	1. *Trainee Notebook*, pages T10.3.1 - T10.3.12
	2. Use the management audit checklist	2. Management Audit Checklist	2. Recording data on chalkboard	2. *Instructor Notebook*, pages 10.3.1 - 10.3.5
	3. Analyze management problems	3. Problem solving	3. Frequent reference to *Trainee Notebook* materials	
			4. Trainee problem solving and reporting results	

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 10: Management Behavior

Lesson 1: Management/Administration and Treatment Plant Operations

Lesson 1 of 3 lessons Recommended Time: 60 minutes

Purpose: Internal management and administrative procedures can have a significant impact on wastewater treatment facility performance. This lesson introduces the subject of management and relates it to wastewater treatment facility operations and performance. It guides the trainee toward determining when and how the troubleshooter will be able to evaluate and assist in resolution of management related problems at wastewater treatment facilities.

Trainee Entry Level Behavior: Trainees should have achieved the learning objectives specified for Unit of Instruction 2, *Elements of Troubleshooting*, before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee whill be able to:

1. By solving a case history problem, identify that technical problems may be caused by a deficiency in management, supervision or administration and that the solution to the problem is correction of management deficiencies.
2. From memory, describe why good management is essential to good wastewater treatment plant operations and maintenance.
3. From memory, describe how the troubleshooter can assist in solving management related O & M problems and explain when it is appropriate for the troubleshooter to address management problems.

Instructional Approach: Trainee problem solving, class discussion and illustrated lecture.

Lesson Schedule: The 60 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 30 minutes	Trainee Problem Solving
30 - 45 minutes	Management and Why It's Important
45 - 60 minutes	Relating Troubleshooting to Management

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T10.1.1 - T10.1.2 , "Problem Statement and Answer Sheets."
2. *Field Manual for Performance Evaluation and Troubleshooting in Municipal Wastewater Treatment Facilities*, pages 295-314.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 10.1.1 - 10.1.10, Unit 10, Lesson 1.
2. *Trainee Notebook*, pages T10.1.1 - T10.1.2 , "Problem Statement and Answer Sheets."
3. Slides 179.2/10.1.1 - 179.2/10.1.3.

Instructor Materials Recommended for Development: None

Additional Instructor References: None

Classroom Set-Up:

1. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees.
2. Instructor table with lectern.
3. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.
4. Easel with pad.
5. 35mm carousel projector with remote control changer at instructor table.
6. At least four empty carousel trays.
7. Overhead projector.
8. Chalk, felt-tip markers, erasers, etc.
9. Six to eight chairs randomly spaced at back and sides of room for visitors.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Introductory Management Problem (30 minutes)	Use Slide 179.2.10.1.1 Slide 179.2/10.1.1 is a blank
A. DO NOT INTRODUCE THIS AS A LESSON ON MANAGEMENT	Guide: Problem Description on page T10.1.1 in the *Trainee Notebook*
1. Have class refer to page T10.1.1 in *Trainee Notebook*, "Problem Statement and Answer Sheets."	
2. Begin problem solving as if it were a technical problem which requires technical solution.	
B. Have students read problem, then discuss among their trainee groups.	
C. Trainee groups should answer questions asked on answer sheet, *Trainee Notebook*, page T10.1.1	Guide: Allow 10 minutes for Steps B and C.
D. Have trainee groups briefly present their answers.	Guide: Allow 5 minutes for Step D
E. Respond to trainee group presentations of their answers, then proceed by reading the second part of the problem.	
1. Most likely cause of problem is overloading which could be caused by:	
a. Storm water inflow or infiltration.	Write the list of possible causes on the chalkboard as the trainees identify them. Minimum listing sought is at left.
b. New sewer connections, probably industrial.	
c. An industry with an occasional heavy discharge.	
d. Digester feed sludge concentration too high at times.	
e. Withdrawing too much digested sludge to dewatering and disposal.	
f. Overpumping feed sludge to the digesters at one time.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Note that three of the six possible causes of overloading are directly related to internal plant operational procedures.	
F. Instructor reads aloud:	
"All of the above were investigated with negative results. However, the case was not dropped. The Chief Operator recommended that you check these sources more closly Weather records for the individual periods revealed no rainstorms so it was definitely ruled out. Next, the Chief Operator looked again at his list and quickly determined that no new connections had occurred. Of the four remaining, three were directly connected to internal operations. Therefore, a closer examination of these would be made before checking item No. 3.	Refer to *Trainee Notebook*, page T10.1.2 for second part of problem statement and answer sheet.
A day by day investigation of plant records revealed that the regular digester operator was off at various times and was replaced by another plant operator. This operator was given a variety of oral instructions which weren't completely understood and he probably had overdone all three operations, thus leading to most of the plant's problems.	
G. Have class develop list of alternative corrective actions by answering questions on *Trainee Notebook*, page T10.1.2 and discuss them as they develop.	Write trainee responses on chalkboard as they are surfaced.
1. Is this a technical or a management problem? Answer: Management	
2. What action could the Chief Operator take to correct the problem?	Try to guide class to the six alternatives listed on Slide 179.2/10.1.2 which will be shown in the next section of problem solution.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
a. Terminate relief operator.	
b. Terminate the regular operator for not giving good instructions.	
c. Reprimand both of them.	
d. Establish and post job procedures.	
e. Establish training for relief operator.	
f. Provide a better system of supervision.	
H. Show Slide 179.2/10.1.2 and have class discuss the merits of each alternative. Lead class toward recommending items 4, 5 and 6 as a constructive solution to the problem as opposed to the punitive solutions 1, 2 and 3.	Use Slide 179.2/10.1.2 Slide 179.2/10.1.2 is a word slide which reads: "Possible Corrective Actions 1. Terminate relief operator 2. Terminate the regular operator for not giving good instructions 3. Reprimand both of them 4. Establish and post job procedures 5. Establish training for relief operators 6. Provide a better system of supervision"
II. Management and Why It is Important (15 minutes)	Use Slide 179.2/10.1.3 Slide 179.2/10.1.3 is a blank.
A. Introduction to Lesson - Objectives of the lesson on Management Behavior as applied to troubleshooting treatment plants:	
1. Management behavior is an important factor in how well a treatment plant is operated.	Guide: Use this section to introduce the lesson and to relate management to overall plant operations. Use preceding problem as a lead-in.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Management is the system by which the capabilities of people and plant facilities are combined to get the most out of the waste treatment systems of the plant.	
3. Management requires management skills which many persons are very weak on.	Management skills are individual personal traits.
4. Management can be facilitiated with "management systems," i.e., systematic programs for accomplishing the various management responsibilities within a treatment plant.	Management skills and systems will be developed in detail in the next lesson in the unit.
5. Management systems can be evaluated and improved by using the Process of Troubleshooting, just as physical systems can be.	
B. Management of Wastewater Treatment Plants	
1. We think of "management" as something applied to a business or industry. In what ways does it apply to a treatment plant? Use the following logic to develop the argument that treatment plants need management.	
2. Characterizing a waste treatment plant. A treatment plant may be thought of as being:	
a. A manufacturing enterprise - handling clean water and an unwanted by-product, sludge.	
b. A materials handling facility - handling tons of materials per day: solids, liquids and gases.	
c. A controlled biological environment - a place where we let nature "do its thing".	

LESSON OUTLINE | **KEY POINTS & INSTRUCTOR GUIDE**

   d. A public service - providing clean water for public rivers, streams, lakes and oceans.

3. Thus, in a general sense, a treatment plant is no different from other establishments in that:
   a. There is a job to be done, a product to be produced.
   b. High product quality is sought - in fact, is legally required.
   c. There is a cost, thus cost efficiency is necessary.
4. Having to meet all of the above requirements, is there any doubt that treatment plants need good management?

Key Point: Treatment plants need management just like anything else

C. Making a Treatment Plant Work

1. The primary function of a treatment plant is to produce an acceptable effluent, one which meets permit requirements, effluent limitations and which prevents the degradation of water quality in the receiving body of water.
2. Treatment plants operate through various unit operations and processes which employ:
   a. Physical forces: heat, gravity, pressure, etc.
   b. Chemical reactions.
   c. Biological activity - hopefully controlled.
3. Treatment plant processes require (among other things):

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

a. Equipment: tankage, mechanical devices

b. Materials: chemicals, media, oxygen

c. Transport mechanisms: pipes, channels, shovels, trucks

d. Control mechanisms: valves, weirs, dosage controls

e. Analytical devices: gauges, samplers, laboratories

4. What makes treatment plant processes function?

   a. Operations provide the right mix and timing of materials, equipment, etc.

   b. Maintenance allows operations to proceed normally.

   c. Operation of a plant is managed: it is

      1) Scheduled
      2) Staffed
      3) Paid for
      4) Equipped

5. People make operation possible and the "operating program" which assures that people perform as planned is management

   Good management is the means by which people (plant personnel) do the right things at the right time to get the most out of the treatment facility.

6. Illustrate, by drawing the following diagram on the chalkboard.

677

Management → People → Operation → Processes → Wastewater Treatment → Clean Water

The diagram should be explained in these simple terms:

a. Management determines what people do,

b. To operate treatment processes,

c. Which comprise a wastewater treatment plant,

d. Which produces clean water.

7. Allow for discussion and questions at this point.

III. Relating Troubleshooting to Management in a Treatment Plant (15 minutes)

A. The Role of a Troubleshooter in Dealing with Management Problem

Note: This question is often of great interest and becomes the subject of considerable discussion. Discussion should be allowed to continue as long as it is fruitful and relevant to the overall lesson.

Also, it should be noted that different states and agencies may have different policies on this question - of how deeply a troubleshooter should get involved in managent problems.

1. Upon visiting a treatment plant, troubleshooters should be able to recognize when plant operational problems may be caused by management difficulties (hopefully this lesson will assist them in recognizing management problems)

2. With a knowledge of management systems

Key Point: This diagram should be used to illustrate how management determines treatment plant operation and performance

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
(to be covered in the lesson following this section) troubleshooters, in many cases, should be able to provide constructive assistance.	Information on management systems and management skills is developed in Unit 10, Lesson 2.
3. This leaves the question of whether they should attempt to provide assistance.	
a. This may depend in part on the reason for visiting the plant in the first place and the circumstances by which a troubleshooter may be asked to help.	Guide: Note that this point has already been discussed in part in Unit of Instruction 2, *Elements of Troubleshooting*.
b. It depends upon the troubleshooter's relationship with the plant operator and superintendent and past relationships between the agency and the municipality.	Use the blackboard to bring out points during the discussion.
c. If there is doubt in the troubleshooters mind as to whether he/she should involve himself/herself, he/she should consult his/her supervisor before proceeding.	
d. Sometimes problems of a management nature should be "bounced up" to people in the agency who have been on the job longer and who are better known to the municipal people. In some cases, they can be better handled on the "political" level than on the technical level.	Key Point: This question boils down to the point that the troubleshooter's judgment must be used in determining if and how he/she should get involved in management problems
e. When getting involved in a management problem, a troubleshooter must remember that he/she cannot solve it, but he/she can work with others to help them solve it.	
4. Call for general class comment and discussion on this issue.	

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 10: Management Behavior

Lesson 1: Management/Administration and Treatment Plant Operations

Trainee Notebook Contents

Problem Statement and Answer Sheets T10.1.1

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Problem Statement and Answer Sheets

You are an operations consultant and have been called out to look at a three year old activated sludge plant that treats all of its waste sludge in a two-stage anaerobic digester system. Grit is removed in a degritter ahead of the primary clarifier. Primary raw sludge is concentrated in a flotation thickener. Both sludges are fed into the digester by a pump operating on a time clock. During the past year, the plant has experienced frequent primary digester upsets requiring lime additions.

After inspecting the plant, you graph the results of digester lab tests to get a clearer picture of what has been happening. The graph reveals erratic volatile acid to alkalinity ratios with each upward swing of volatile acid followed by a drop in pH at which point lime was added. The total amount of lime used was 40,000 lbs at a cost of $800 for the year.

You and the Chief Operator know that he must correct the condition, improve digester stability and reduce operational costs. You and the Chief Operator begin to investigate the problem to determine possible causes and corrective actions.

Working with the other members of your group and using the *Field Manual for Performance Evaluation and Troubleshooting O & M Problems at Municipal Wastewater Treatment Facilities*, pages 295-314, as a reference, answer the following questions.

1. What are the possible causes for this problem?

2. How would you narrow down the list of possible causes?

3. Do you think the problem may be due to other causes?

STOP! Wait for the Instructor to Give Additional Information Before Going On.

T10.1.1

After listing all the possible causes of digester upsets, you and the chief operator concluded that organic or hydraulic overloading are the most likely causes. Further "brainstorming" led you to believe that the frequent overloading observed was due to one of the following conditions:

1. Storm water inflow or infiltration;
2. New sewer connections, probably industrial;
3. An industry with an occasional heavy discharge;
4. Withdrawing too much digested sludge to dewatering and disposal;
5. Digester feed sludge concentration too high at times;
6. Overpumping feed sludge to the digesters at times.

All of the above were investigated with negative results. However, the case was not dropped. The chief operator checked these causes more closely. Weather records for the individual periods revealed no rainstorms eliminating inflow and infiltration as a likely cause. The chief operator's review of the industrial source file indicated that there had been no new sewer connections. Of the four remaining causes, three are directly related to internal plant operations. Therefore, you examine these more closely before checking item 3.

A thorough check of the plant operating logs revealed that the regular digester operator was off at various times and was replaced by another plant operator. The replacement operator was given oral instructions which were not completely understood by him. He probably performed all three operations (items 4 - 6) incorrectly causing most of the digester operating problems.

Questions:

1. Is this a technical problem or a management problem?

2. What actions could the chief operator take to correct the problem?

3. What actions would you recommend? Why?

4. Did you jump to the conclusion that this was only a technical problem? If so, why?

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 10: Management Behavior

Lesson 2: Troubleshooting Management Systems

Lesson 2 of 3 lessons Recommended Time: 90 minutes

Purpose: This lesson differentiates between management skills and management systems. The troubleshooter's role in evaluating management systems and recommending corrective action programs is discussed. Maintenance management systems are discussed in detail.

Trainee Entry Level Behavior: Trainee should have achieved the learning objectives specified for Unit 10, Lesson 1 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson the trainee will be able to:

1. From memory, describe how the troubleshooter may identify management related problems as the possible cause of O & M deficiencies at wastewater treatment plants by listing the observations and other indicators of potential management problems at treatment plants.

2. From memory, define and contrast the terms *management skills* and *management systems* and describe the troubleshooter's role in dealing with problems in each area.

3. Explain the importance of maintenance management to achieving overall treatment goals.

4. Using references, list the components of a maintenance management system, explain the importance of each component and describe how the troubleshooter would evaluate a maintenance management system.

5. From memory, list the major factors external to the treatment plant that may affect plant management and explain the significance of each factor.

Instructional Approach: Illustrated lecture with class discussion.

Lesson Schedule: The 90 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 10 minutes	Identifying Management Problems
10 - 35 minutes	Management Systems
35 - 75 minutes	Developing Management Systems
75 - 90 minutes	Dealing with External Management Problems

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T10.2.1 - T10.2.25, "Maintenance Management."

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 10.2.1 - 10.2.12, Unit 10, Lesson 2.

2. Slides 179.2/10.2.1 - 179.2/10.2.13.

Instructor Materials Recommended for Development: None

Additional Instructor References:

1. *Maintenance Management Systems for Municipal Wastewater Facilities*, EPA 430/9-74-004, Municipal Operations Branch, U. S. Environmental Protection Agency, Washington, D.C. (October, 1973).

Classroom Set-Up: As specified in Unit 10, Lesson 1.

LESSON OUTLINE

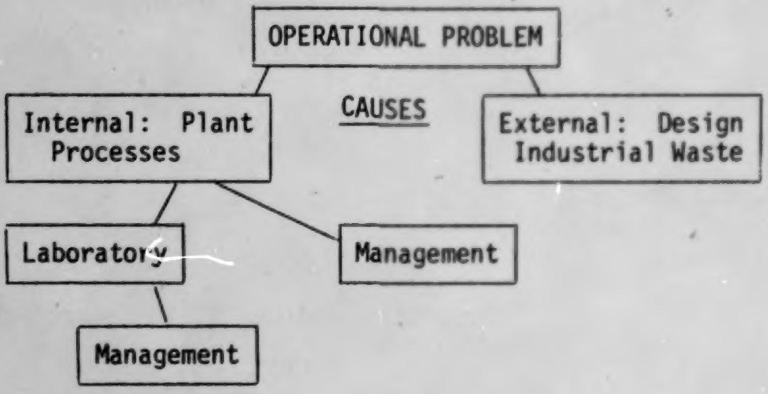
I. Identifying Management Problems (10 minutes)

A. Management problems are identified through measures of plant performance - just as other plant problems are identified.

1. Is plant effluent meeting standards?
2. Are processes functioning properly?
3. Is the operator getting the most from his/her plant?

B. Often, the troubleshooter cannot determine immediately that a problem is due to a management deficiency rather than a technical deficiency. However, he/she should always consider management problems to be among the alternatives he/she has to choose from in determining the cause of operational problems.

C. Sometimes a deficiency in plant operation is several steps removed from a management problem that is the cause.



D. Management problems can occur in any of several management areas and have a serious impact on plant operations.

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/10.2.1
Slide 179.2/10.2.1 is a blank

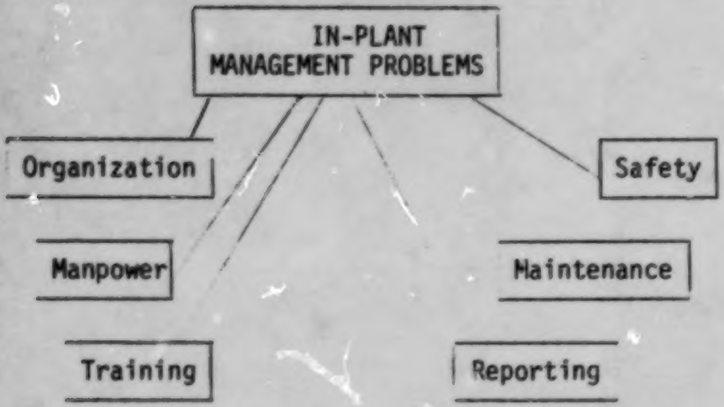
Refer trainees to chart, Process of Troubleshooting, Line 2 - Formulating Alternative Solutions, *Trainee Notebook*, page T2.2.8

Use Slide 179.2/10.2.2
Slide 179.2.10.2.2 is identical to the schematic on the left.

Plant operations can be hurt by poor management.

Use Slide 179.2/10.2.3
Slide 179.2/10.2.3 is identical to the schematic on the left of the next page.

LESSON OUTLINE



E. Key step in the Process of Troubleshooting as applied to Management Problems. Refer to Chart-Process of Troubleshooting, *Trainee Notebook*, page T2.2.8.

1. Line 1 - Analyze and learn
2. Step C - Visit Plant, meet and listen, observe, review

F. Observations to make while troubleshooting

1. Relate listing on Slide 179.2/10.2.5 to possible management defects at the plant.

KEY POINTS & INSTRUCTOR GUIDES

Guide: Use Slide 179.2/10.2.4 to relate the Process of Troubleshoot-shooting to management.

Use Slide 179.2/10.2.4
Slide 179.2/10.2.4 is a word slide which reads:

"Process of Troubleshooting Applied to Management"

Key Step: Analyze and Learn
Visit Plant
Meet and Listen
Observe
Review"

Key Point: Stress importance of talking to plant personnel and in observing what's happening at a treatment plant.

Use Slide 179.2/10.2.5
Slide 179.2/10.2.5 is a word slide which reads:

"Observations to Identify Management Problems

Busy People, Little Work Done
Disabled Equipment
No Safety Rails or Guards
Poorly Kept Grounds
Sampling Techniques
Any Visible Sign of Management Laxity"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
2. Relate items on slide 179.2/10.2.6 to management related O & M problems.	Use Slide 179.2/10.2.6 Slide 179.2/10.2.6 is a word slide which reads: "Indicators of Management Problems Long Record of Process Accidents Obvious 'Dry Labbing' No Apparant Chain of Command Lack of Maintenance Records Incorrect Data in Reports Poorly Trained Staff"
G. Troubleshooting Management Problems 1. Once problems are identified that are caused by management problems or deficiencies, the troubleshooter may proceed in several ways, depending on the nature of the problem, the situation and his/her relationship with the plant operator. Among the things he/she can do are: a. Let the operator know what the problem is and then bow out and let the operator handle it. b. Suggest a remedy or solution to the problem. c. Work with the operator to help him/her correct the problem. d. Provide information, such as on the development of an appropriate management system. e. Assist the operator in designing and instituting appropriate management systems.	Use Slide 179.2/10.2.7 Slide 179.2/10.2.7 is a blank
II. Management Systems (25 minutes) A. Management, in a treatment plant or anywhere else, is getting things done through people.	Guide: The point of this section is to show that there exists various management systems, which when used to operate a treatment plant, facilitate good management.

B. Good management means having control over the physical facilities and processes in a plant, control that is obtained through the operation of those facilities by people. (Even in cases where a process is automatically operated, it takes people to program and monitor those operations.)

C. Management activities are based on a collection of personal and professional skills, skills which many people have a little of, but which some people can learn.

   1. Some people have ample management talent.

   2. Others have little or none, including many engineers and scientists.

D. Management skills can be supplemented and strengthened by using management systems.

   Management systems:

   1. Are organized programs designed to help people perform and meet their management responsibilities.

   2. Put management on a very systematic and routine basis, and thus simplify it considerably.

   3. Can help the unskilled manager to do his/her job successfully.

E. Identifying Management Systems

   1. Recorder should set up two columns on the chalkboard.

      Management Systems   Management Skills

   2. Instructor should categorize each input as a "skill" or a "system."

   3. Recorder should write down each input.

   4. Some likely responses will be:

Guide: Select one trainee to be the class recorder, using the chalkboard. Have the class contribute their ideas as to what are management skills and systems. The instructor should categorize each input as a "skill" or a "system."

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDES

a. Management Systems

Maintenance
Safety
Staffing
Training
Personnel
Contingencies
Reporting
Record Keeping
Bookkeeping
Planning
Communication
Organization

b. Management Skills

Supervision
Organization
Interviewing
Contingencies
Delegation
Writing
Communication
Decision Making

5. Characteristics of Management Systems

Guide: With these lists on the chalkboard, make the following points.

a. Management systems are developed, thus they serve as management tools, even for persons with poor management skills.

b. There are aides, and guidelines and manuals for the development of management systems. One need not be an expert.

c. Management systems make it possible to overcome deficiencies in management skills.

d. Management systems make it possible to develop and improve management skills in individuals.

e. Management systems give the troubleshooter a target for troubleshooting management problems in a treatment plant.

F. Troubleshooting Management Systems

Troubleshooters can deal with management systems, even if they have few management skills themselves.

Key Point: By observing and understanding management systems, a troubleshooter can assist an operator in dealing with his/her management problems.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
1. Troubleshooters can note the presence or absence of a necesarry management system in a treatment plant.	
2. Troubleshooters can recommend the institution of a management system.	
3. Troubleshooters can assist operators and superintendents in employing and developing management systems.	
4. EPA and others have developed guides, and programs for management systems, i.e., staffing, maintenance, training, safety. Troubleshooters can utilize these materials.	
5. Troubleshooters cannot teach an operator how to develop management skills	Management skills can be developed through training. Troubleshooter's role may be to identify appropriate training courses to the operator and his supervisors.
6. Troubleshooters can only solve management problems indirectly - through the operator and the use of management systems.	
III. Developing Management Systems (40 minutes)	
A. When called upon, a troubleshooter may be able to assist an operator in the development of needed management systems in a plant.	
1. EPA and other materials are available to help in this activity. Example, cite EPA manuals.	
a. *Maintenance Management Systems for Municipal Wastewater Facilities.*	Much of this section is taken from material in this EPA manual, *Maintenance Management Systems for Municipal Wastewater Facilities.*
b. *Estimating Staffing for Municipal Wastewater Treatment Facilities.*	Guide: As an example of developing management systems, this section will focus on setting up a maintenance management system.
B. Components of Maintenance Management Systems	Guide: Select one trainee to be a recorder at the chalkboard. Have class suggest what different components of a maintenance management system would be and record on board.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
1. Use Slide 179.2/10.2.8 to list components as taken from the Table of Contents of the EPA manual, *Maintenance Management Systems for Municipal Wastewater Facilities*. Leave slide on. For the remainder of this section, reference is made to material in the *Trainee Notebook*, reprinted from the EPA manual, *Maintenance Management Systems for Municipal Wastewater Facilities*. Have students follow lesson by using their *Trainee Notebooks*, pages T10.2.1 to T10.2.19.	Use Slide 179.2/10.2.8 Slide 179.2/10.2.8 is a word slide which reads: "Components of Maintenance Management System Equipment Record System Scheduling and Planning Storeroom and Inventory Personnel and Organization Costs and Budget Correlating the Components Into a Complete System"
2. Equipment record system	Reference: *Trainee Notebook*, page T10.2.1
An example of an equipment records system for small plants would be a single card file system, with one card used for each piece of equipment.	
3. Maintenance scheduling and planning systems are needed so that things get done when they are supposed to.	
a. Typical daily and weekly routine maintenance schedules	Reference: *Trainee Notebook*, pages T10.2.2 and T10.2.3
b. Typical Maintenance Work Order	*Trainee Notebook*, page T10.2.4
4. Storeroom and Inventory System	
a. Sample inventory card	*Trainee Notebook*, page T10.2.5
5. Personnel and Organization	
a. Manual has listing of various job titles and responsibilities.	
b. Typical maintenance organization charts	
1) Plant under 10 MGD	*Trainee Notebook*, page T10.2.6
2) Plant 10-50 MGD	*Trainee Notebook*, page T10.2.7
6. Costs and Budget	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
a. Maintenance Cost Trends - very important records to determine overall level of plant maintenance and performance.	*Trainee Notebook*, page T10.2.8
C. Putting the components together into one maintenance management system.	*Trainee Notebook*, pages T10.2.9 through T10.2.18
1. *Trainee Notebook* pages T10.2.9 - T10.2.18 provide detailed guidance on developing a maintenance management system for a small, a medium or a large treatment plant.	
2. In large plants, the ultimate system is a computerized maintenance program.	*Trainee Notebook*, page T10.2.19
D. Evaluating Maintenance Management Systems	*Trainee Notebook*, pages T10.2.20 through T10.2.25
1. EPA provides evaluation guidelines for maintenance management systems that are very useful for troubleshooting such systems.	Briefly review guidelines with class.
E. Other Management Systems	
1. Other management systems also lend themselves to a systematic development, similar to maintenance management.	
2. Troubleshooters have a great opportunity to assist municipalities in upgrading and developing such systems.	
IV. Dealing with External Management Problems (15 minutes)	
A. Troubleshooters should recognize that plant operators and superintendents must deal with a variety of management problems of an origin external to the plant.	Guide: This topic should be covered briefly, with as much discussion as there is interest and as time allows.
1. The larger the municipality, the more impact external management problems are likely to have.	
2. Many external problems cannot be tackled by troubleshooters directly, although they may be able to provide guidance if	

LESSON OUTLINE

they have experience in those areas. However, troubleshooters must be aware of, and should be understanding of the external management problems confronting treatment plant operators.

B. Use Slide 179.2/10.2.9 to discuss external management concerns within a municipal government.

C. There are also impacts from outside the municipal government. Use Slide 179.2/10.2.10 to guide class discussion on these external impacts.

D. Summarize Lesson

1. Use Slides 179.2/10.2.11 and 179.2/10.2.12 to help in summary.

KEY POINTS & INSTRUCTOR GUIDES

Key Point: Troubleshooters must recognize the problems that an operator or superintendent is faced with.

Use Slide 179.2/10.2.9
Slide 179.2/10.2.9 is a word slide which reads:

"Municipal Management Systems Impacting Treatment Plants

Mayor/City Manager's Office
Engineering
Personnel
Purchasing
Legal
Finance and Budget"

Use Slide 179.2/10.2.10
Slide 179.2/10.2.10 is a word slide which reads:

"External Relationships

Labor Unions
OSHA
EEO Commission
NLRB
State Water Quality Agency
Regional Planning Organization(s)
EPA"

Use Slide 179.2/10.2.11
Slide 179.2/10.2.11 is a word slide which reads:

"Management Behavior Summary

Management is a Key to Plant Operations
Troubleshooters Can Work With Operators to Improve Management
Management Can Be Accomplished With Management Systems"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
	Use Slide 179.2/10.2.12 Slide 179.2/10.2.12 is a word slide which reads: "Important Management Systems Include Organization Manpower Training Reporting Maintenance Safety Communication"
2. Use any remaining time for discussion.	Use Slide 179.2/10.2.13 Slide 179.2/10.2.13 is a blank.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 10: Management Behavior

Lesson 2: Troubleshooting Management Systems

Trainee Notebook Contents

Single Card Equipment Records System for a Small Plant T10.2.1

Typical Small Plant Maintenance Scheduling and Planning System - Daily Tasks T10.2.2

Typical Small Plant Maintenance Scheduling and Planning System - Weekly Tasks T10.2.3

Sample Maintenance Work Order T10.2.4

Sample Inventory Card T10.2.5

Maintenance Organization and Staffing for Small Plants - Less than 10 MGD T10.2.6

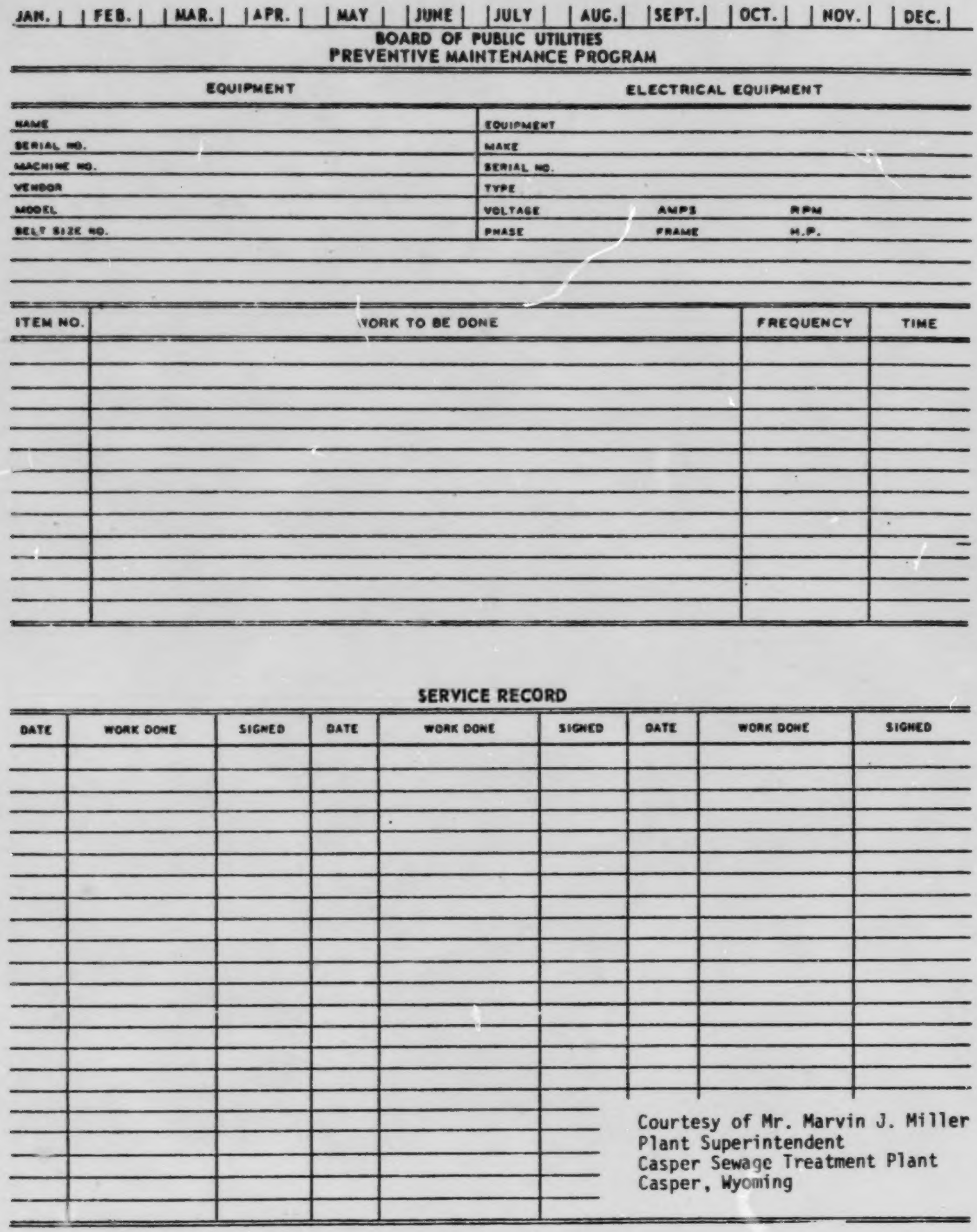
Maintenance Organization and Staffing for 10-50 MGD Plant T10.2.7

Maintenance Costs Monitoring and Control Data . . . T10.2.8

Correlation of the Basic System Features Into A Working Maintenance Management System T10.2.9

Information Flow in Computerized Maintenance Management System T10.2.19

Maintenance Management System Evaluation Guidelines T10.2.20



JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.

BOARD OF PUBLIC UTILITIES
PREVENTIVE MAINTENANCE PROGRAM

EQUIPMENT	ELECTRICAL EQUIPMENT
NAME	EQUIPMENT
SERIAL NO.	MAKE
MACHINE NO.	SERIAL NO.
VENDOR	TYPE
MODEL	VOLTAGE AMPS RPM
BELT SIZE NO.	PHASE FRAME H.P.

ITEM NO.	WORK TO BE DONE	FREQUENCY	TIME

SERVICE RECORD

DATE	WORK DONE	SIGNED	DATE	WORK DONE	SIGNED	DATE	WORK DONE	SIGNED

Courtesy of Mr. Marvin J. Miller
Plant Superintendent
Casper Sewage Treatment Plant
Casper, Wyoming

Single Card Equipment Records System
for a Small Plant

DAILY ROUTINE

NOTE:

1. SAFETY FIRST SHALL BE STRICTLY OBSERVED.
2. WORK AREAS SHALL BE KEPT CLEAN AT ALL TIMES. (WASHED & DISINFECTED)
3. ANYTHING UNUSUAL SHOULD BE REPORTED.

Wailoa and Pua Pump Stations

1. Make visual inspection
2. Check pump packing
3. Check sump pump-oil
4. Check flo-matcher water level and temperature
5. Alternate variable speed motors manually
6. Bleed air receiver tank (s)

Sub Stations

Hilo

1. Clean grating (Hose down)
2. Visual check: Pump packing-sump pump

Peninsula

1. Bleed compressor tank
2. Check sump pump

Keaukaha

1. Bleed compressor tank
2. Check sump pump

Treatment Plant

Grit Chamber

1. Grind rags and wash down
2. Visual inspect sprayer nozzles
3. Remove grit once a week

Clarifier

1. Hose down as required scum pit
2. Hose down
3. Pump out

Sludge Pump Building

1. Check sump pump
2. Visual check
3. Check sludge pump-oil level

Courtesy of Mr. Harold Sugiyama
Bureau of Sewers & Sanitation
Hilo Sewage Treatment Plant
Hilo, Hawaii

Typical Small Plant Maintenance Scheduling and Planning System

Daily Tasks

ROUTINE DUTIES — TO BE SCHEDULED BY FOREMAN

Weekly

Grit Chamber

Remove sediments and floating solids

Sludge Centrifuge Building

1. Check centrifuge torque converter oil level
2. Remove sludge (Run centrifuge with water if sludge is not removed)

Monthly

Sludge Pump Building

1. Grease air compressor bearings
2. Clean air filter

Wailoa Pump Station

1. Check compressor oil level
2. Clean air filter

General Duties

January and July

Pua Station

Grease—all bearings

1. Electric motor bearing
2. Drive shaft bearing
3. Pump bearing
4. Change packing as required (complete)
5. Exercise all valves — grease shaft
6. Wash floors as required

Sludge Centrifuge Building

Grease all bearings

February and August

Wailoa Pump Station

Grease all bearings

1. Electric motor
2. Pump drive shaft
3. Pump
4. Change packing as required (complete)
5. Exercise all valves — grease shaft
6. Wash floors as required

Courtesy of Mr. Harold Sugiyama
Bureau of Sewers & Sanitation
Hilo Sewage Treatment Plant
Hilo, Hawaii

Typical Small Plant Maintenance Scheduling
and Planning System

Weekly Tasks

T10.2.3

Date ____________

Work Order No. ____________________

Location	Requested By: (Phone)	Priority:

Equipment Name	No.

☐ Inspect ☐ Replace ☐ Service

☐ Repair ☐ Overhaul ☐ Paint

Work Description

Work Performed/Comments

Maintenance Superintendent

Job Estimate

Labor $ ____________

Material $ ____________

Work Record

Personnel Assigned	Manhours	Date	Work Done	Parts & Materials
Total				

Work Completed By ______________________________ Date ____________

Work Accepted By ______________________________ Date ____________

Sample Maintenance Work Order

STOREROOM INVENTORY CARD

Item Description -

Item No. ________

Isle No. ________

Bin No. ________

Quantity Maximum ________________ Minimum ________________

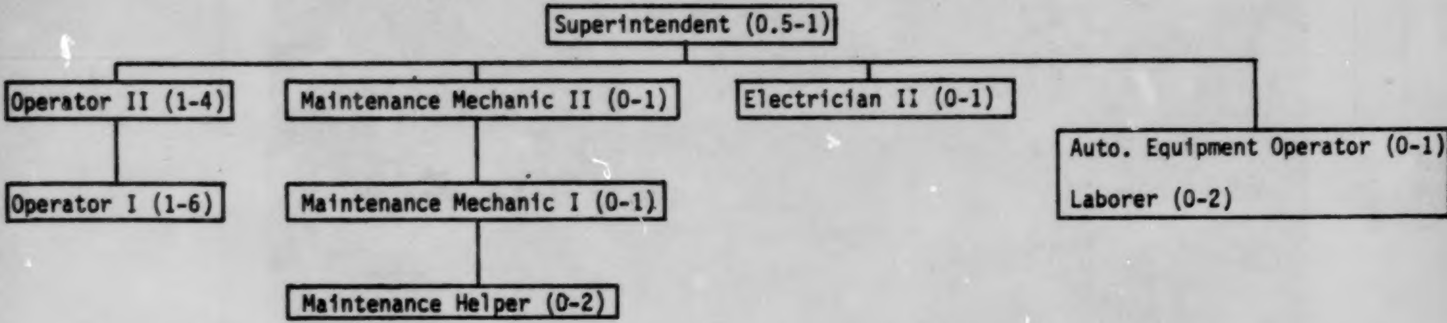
Reorder ________________

INVENTORY INFORMATION

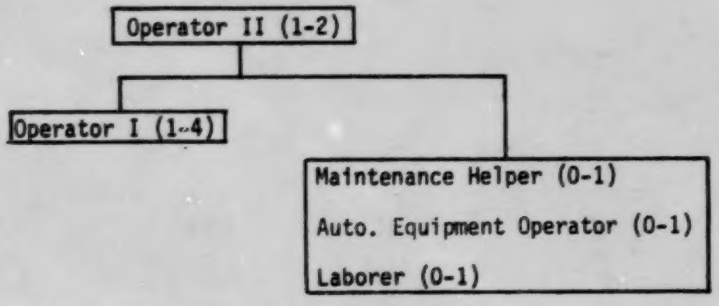
Quantity Used or Stocked	Date	Signed	Quantity on Hand	USAGE OR SUPPLY INFORMATION Usage - Work Order No. Supply - Purchase Order No.

Sample Inventory Card

MAINTENANCE ORGANIZATIONAL CHART NO. 1

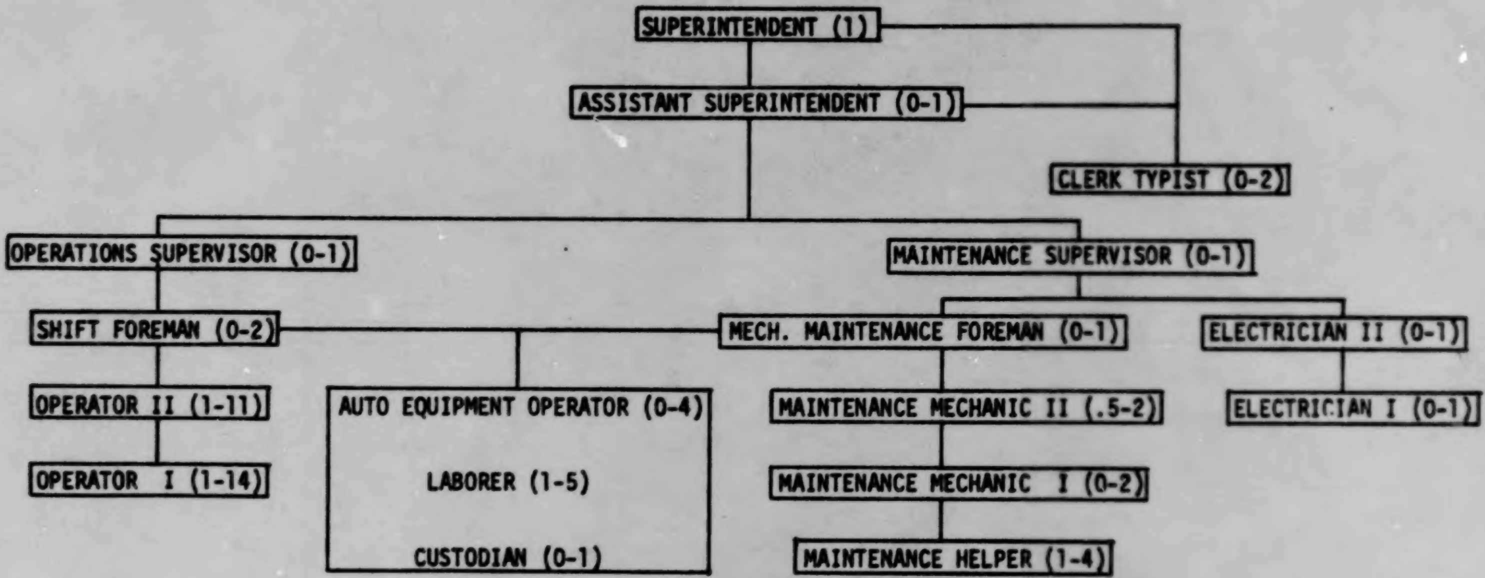


MAINTENANCE ORGANIZATIONAL CHART NO. 2



Maintenance Organization and Staffing for Small Plants
Less than 10 MGD

T10.2.7

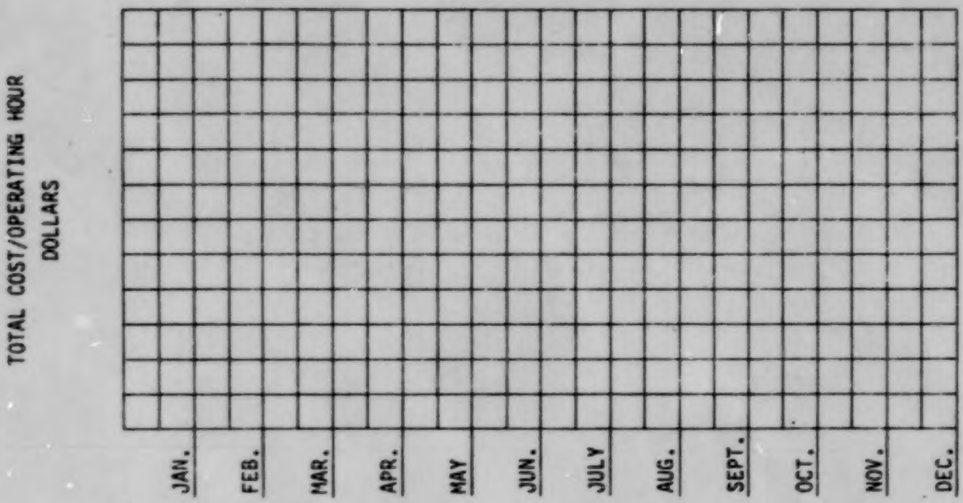

SUPERINTENDENT (1)
ASSISTANT SUPERINTENDENT (0-1)
CLERK TYPIST (0-2)
OPERATIONS SUPERVISOR (0-1)
MAINTENANCE SUPERVISOR (0-1)
SHIFT FOREMAN (0-2)
MECH. MAINTENANCE FOREMAN (0-1)
ELECTRICIAN II (0-1)
OPERATOR II (1-11)
AUTO EQUIPMENT OPERATOR (0-4)
LABORER (1-5)
CUSTODIAN (0-1)
MAINTENANCE MECHANIC II (.5-2)
ELECTRICIAN I (0-1)
OPERATOR I (1-14)
MAINTENANCE MECHANIC I (0-2)
MAINTENANCE HELPER (1-4)

Maintenance Organization and Staffing
for 10 - 50 MGD Plant

MAINTENANCE COST TREND FORM

EQUIPMENT NAME ______________________ LOCATION ____________________

I.D. NO. ______________________



MAINT. COST/HOUR $ / DATE	OPN. HOURS	REPAIR LABOR HOURS	PM LABOR HOURS	TOTAL LABOR HOURS	MAT'L COST	LABOR COST PER OPN. HOUR	MAT'L COST PER OPN. HOUR	TOTAL COST PER OPN. HOUR
JAN.								
FEB.								
MAR.								
APR.								
MAY								
JUN.								
JULY								
AUG.								
SEP.								
OCT.								
NOV.								
DEC.								

REMARKS ____

Maintenance Costs Monitoring and Control Data

SECTION IX
CORRELATION OF THE BASIC SYSTEM FEATURES INTO A WORKING MAINTENANCE MANAGEMENT SYSTEM

General

This section provides examples of maintenance management systems for various size plants. The following three examples are for a small facility, a middle size facility, and a large facility. The examples assume all facilities are properly staffed and are operating continuously. The example maintenance systems for the three size facilities are all workable systems. However, they are not intended to be rigid formats for all facilities within a given size range. In developing a system for a particular plant, a person may use any combination of the feature techniques from larger or smaller plants and may adapt them to his particular plant. Because various procedures can be used in a variety of plants, no size range has been assigned to these examples. A person preparing a new system or updating an existing system can use these examples to help develop the maintenance management system which best fits his particular plant.

Each example is broken down into the five basic features of a maintenance management system. This breakdown corresponds to this manual's format which has a separate section on each of these five basic features. This permits persons reviewing these examples of maintenance management systems to quickly refer to the appropriate section in this manual for a discussion of any item described in the examples.

Source: *Maintenance Management Systems for Municipal Wastewater Facilities*, Section IX, U. S. Environmental Protection Agency, Washington, D.C. (October, 1973)

EXAMPLE MAINTENANCE MANAGEMENT SYSTEM

SMALL FACILITY

General

This example is based upon a facility with a superintendent and several operators having to perform the operations and maintenance work and keep the maintenance records.

Equipment Record System

To develop the equipment record system, each item of equipment is numbered. For a small plant, the first equipment item in the pretreatment area is given the number one. All other equipment is numbered consecutively following the wastewater flow through the facility. Multicomponent items are broken down and numbers are assigned to each component requiring any type maintenance tasks. After numbering equipment following the wastewater flow, the numbering is continued to cover all sludge handling equipment. The consecutive numbering was chosen because the number of items in a small plant is usually less than one hundred and the system is simple to apply. The following is a sample of this equipment numbering system:

Number	Equipment Description
1	Mechanically Cleaned Bar Screen
2	Comminutor
3	Raw Wastewater Pump No. 1
4	•
•	•
•	•

MIDDLE SIZE FACILITY

General

This example is for a middle size plant with a maintenance staff performing the major maintenance tasks and a clerk typist to assist in record keeping. The operators will be required to perform minor preventive maintenance on some equipment.

Equipment Record System

To develop the equipment record system, each item of equipment is numbered. All items of equipment are numbered with the equipment in a specified area or building being within a range of numbers. Multicomponent items are broken down and numbers are assigned to each component requiring any type maintenance tasks. The numbering sequence follows the flow through the plant and is continued to cover all sludge handling equipment. The following is a sample of this equipment numbering system:

Number	Equipment Description
1-25	Pretreatment Structure
1	Mechanically Cleaned Bar Screen
2	Comminutor
3	•
•	•
•	•
26-100	Primary Treatment Structure
26	Primary Sedimentation Tank No. 1
27	Manifold Valve No. 1
28	•
•	•

LARGE FACILITY

General

Because of the size and the number of personnel required to efficiently operate a large plant, its maintenance management system must be tailored for that particular plant. The following is an example using a closed system computer approach.

Equipment Record System

To develop the equipment record system, each item of equipment is numbered. The equipment numbering system assigns 1000 numbers to each major stage of the treatment plant. Multicomponent items are broken down and numbers are assigned to each component requiring any type maintenance tasks. The following is a sample of this numbering system:

Number	Equipment Description
1000	Pretreatment Structures
1100	Raw Sewage Pump Station
1110	Bar Screen Room
1111	Influent Bypass Valve
1112	Influent Diversion Gate
1113	Comminutor No. 1
1114	•
1200	Control Room
1210	Pump Motor Control Panel
1211	•
1300	Pump Room
1310	Raw Sewage Pump No. 1
1311	•

EXAMPLE MAINTENANCE MANAGEMENT SYSTEM
(Continued)

SMALL FACILITY

Number	Equipment Description
10	Primary Sedimentation Tank
11	Sludge Collection Mechanism
•	•
•	•
•	•
35	Aeration Tank
36	Aerator No. 1
•	•
•	•
•	•
42	Final Clarifier
43	Sludge Collection Mechanism
•	•
•	•
49	Chlorine Contact Tank
•	•
•	•
58	Raw Sludge Pump No. 1
•	•
•	•
63	Primary Digester
64	Primary Digester Stirring Mechanism
72	Sludge Drying Beds
•	•

MIDDLE SIZE FACILITY

Number	Equipment Description
101-150	Aeration Tanks
101	Aeration Tank No. 1
102	Mechanical Mixer No. 1
103	•
•	•
151-175	Final Clarifiers
151	Final Clarifier No. 1
152	Sludge Collection Mechanism
153	•
•	•
176-250	Operations Building
•	•
•	•
251-275	Chlorine Contact Tank
251	•
•	•
276-300	Sludge Thickener
276	•
•	•
301-325	Digester and Sludge Gas System
301	•
•	•
326-350	Centrifuges
326	•
•	•

LARGE FACILITY

Number	Equipment Description
2000	Primary Treatment Structur
2100	Primary Sedimentation
2110	Influent Manifold
2120	Primary Sedimentation Tank No. 1
2121	Valve No. 1
2122	•
2130	Primary Sedimentation Tank No. 2
2131	•
2132	•
2200	Boiler Room
2210	Raw Sludge and Scum, Pumping System
2211	Raw Sludge Pump No. 1
2212	•
2213	•
2220	Digested Sludge Recirculation System
2221	Sludge Recirculation Pump No. 1
2222	•
2300	Control Room
2310	Motor Control Center No. 1
2320	High Pressure Air System
2321	Compressor

EXAMPLE MAINTENANCE MANAGEMENT SYSTEM
(Continued)

SMALL FACILITY

NOTE: The consecutive numbering system is not flexible with respect to equipment additions and omissions. Therefore, consideration might be given to alternating equipment numbers (1, 3, 5, 7, 9, etc.) or using an alphabetical suffix (12A, 12B, 12C, etc.) to handle this problem.

The list of equipment numbers along with their corresponding equipment descriptions are kept in a folder. This folder is filed and used as an equipment catalog. This catalog provides a convenient list of equipment numbers and their corresponding equipment descriptions.

In a small plant with the superintendent and/or chief operator having to plan, schedule, perform and record maintenance tasks, the equipment record system selected is a single card file system. Figure No. 23 is a sample single card containing nameplate data and preventive maintenance tasks on the front and a record of repairs on the reverse side. These equipment record cards are set upright in a file holder with the top edge exposed. A metal tab is placed on the week of the month in which the next preventive maintenance task is to be accomplished.

MIDDLE SIZE FACILITY

A list of the equipment numbers and their corresponding item descriptions are kept in a notebook. This notebook serves as an equipment catalog. This catalog provides a convenient list of equipment numbers and their corresponding equipment descriptions.

A three card system is used as the plant's equipment record system. Figure No. 22 shows samples of the cards used in this three card system. The first card contains the equipment description, nameplate data, and spare parts list. The second card is a combination work order form and preventive maintenance list. PM frequencies also appear on this card.

The card is removed and copied when preventive work is scheduled. The copy is assigned a work order number and the preventive maintenance tasks to be performed are circled. The third card contains a history record of repairs. When a history record card is filled with information, the completed card is removed and placed in permanent history record and a new card is placed in the file. These cards are maintained in a horizontal tray with the bottom edge of the third card exposed. The third card has a sliding progressive signal positioned on the month for the next scheduled PM inspection; when the inspection is completed, the signal is moved to the month designated for the next inspection. The card also contains a four window multicard

LARGE FACILITY

Number	Equipment Description
2322	Holding Tank
2400	Chlorinator Room
2410	Scales
2420	•
3000	Aeration Tanks
3100	Aeration Tank No. 1
3110	Mechanical Mixer No. 1
3120	•
3130	•
•	•

Equipment numbers, item descriptions and nameplate data are input to the computer. An up-to-date printout of this information is bound and used as an equipment catalog. Additions or deletions of equipment items are made with a computer data card. The computer can be keyed to reproduce any desired portion or all of the equipment catalog information.

A multifile, multipurpose computer system is used for the equipment record system. The preventive maintenance tasks and frequencies are input into the computer files. Additional information on planning and scheduling and cost data are also filed. The system provides a closed-loop maintenance control system that permits one reporting plan. The system provides a total documented control readout of scheduling, cost, equipment history, and manpower requirements.

EXAMPLE MAINTENANCE MANAGEMENT SYSTEM
(Continued)

SMALL FACILITY

Maintenance Planning and Scheduling

The required preventive maintenance tasks are listed on the equipment record cards with their frequencies.

Each week the superintendent reviews all the equipment record cards with tabs denoting work to be performed in the coming week. He uses these cards to prepare the PM work orders for the coming week. A work order priority list is then developed. This priority list includes work orders which will not be completed during the present week and must be carried over to next week. Figure No. 25 is a sample work order form and Figure No. 26 is a sample work order priority list. Current work orders are maintained in a log book with the priority list as the first page. Each Friday, all completed work orders are taken out of the log by the superintendent, applicable information is recorded on equipment record cards and the work orders are placed in a file. This file becomes a history of work accomplished at the facility.

Before an operator or maintenance helper starts to work on a work order, he reviews the notebook containing the preventive maintenance procedures and checklists. Preventive maintenance procedures and checklists are typed on 8½"x11" pages with file

MIDDLE SIZE FACILITY

signal to designate the four weeks in each month. A signal is lowered to denote the specific week in which the task is to be accomplished.

Maintenance Planning and Scheduling

The preventive maintenance tasks and frequencies are listed on the second card of the equipment record system.

The clerk typist reviews the card system weekly and removes the work order cards (second card) for all equipment requiring PM work in the coming week. Copies of this card are made, a work order number assigned, and required PM items circled.

The work orders are forwarded to the maintenance supervisor for his review and to have work priorities established. The work orders and priority list are forwarded to the mechanical maintenance foreman who assigns the work. When the work is accomplished, the work order form is completed and returned to the clerk typist. He records pertinent information and files the work order in a history file of work orders.

The mechanical maintenance foreman reviews all the work orders prior to assigning them to the maintenance staff. He then provides each crew with the PM procedures and checklist for the particular task assigned. The PM procedure and checklist are typed on 8½"x11" pages and have file numbers

LARGE FACILITY

Maintenance Planning and Scheduling

All corrective and preventive maintenar
tasks are initiated by work orders. Figu
No. 24 is an example of the type work ord
used.

A weekly computer printout provides a li
ing of preventive maintenance tasks to
performed in the coming week. The mai
tenance clerk uses this listing to prepa
preventive maintenance work orders. T
preventive maintenance work orders
then forwarded to the maintenance forem
who assigns the work. The records cle
also prepares the corrective maintenan
work orders. The maintenance supervi
reviews all corrective maintenance wo
orders and approves them before forwardi
them to the maintenance foreman.

The maintenance foreman prepares a corre
tive maintenance work estimate before iss
ing the work order to the maintenance sta
Upon completion of the work orders t
clerk forwards the forms to the comput
center. Here the cost information on t
work orders is input to the computer. T
computer program lists equipment numbe
description, total cost of maintenance, pr
ventive maintenance cost, corrective mai
tenance cost, total man-hours and cost

EXAMPLE MAINTENANCE MANAGEMENT SYSTEM
(Continued)

SMALL FACILITY

numbers corresponding to the equipment number of the item the procedure was developed for. The notebook is located with the work order log book. The preventive maintenance procedures are removed and placed on a clipboard for use in the work area. When preventive maintenance procedures are removed, a card is placed in the notebook identifying who is using the procedure. Upon completion of work, the procedure is replaced and the card is removed.

Storeroom and Inventory System

A storeroom is provided to maintain parts and supplies. Each shift operator maintains a key to the storeroom. All storeroom items are numbered and listed in a storeroom catalog. A reference to the item's location in the storeroom is also included in the catalog. The storeroom has consecutively numbered shelves and bins for storing supplies.

To maintain an inventory of each item, a card file is used. The card file has an index card for each item and the cards are filed by item number. The card contains the information as shown on the sample form, Figure No. 27. As items are removed from stock, a storeroom withdrawal slip, (see Figure No. 28) is completed. The withdrawal slip is used

MIDDLE SIZE FACILITY

corresponding to equipment numbers. A sign-out sheet is provided and initialed when a procedure has been removed from the PM procedures file. Upon completion of the work, the procedure is returned and the sign-out sheet updated.

Storeroom and Inventory System

A storeroom is provided for maintaining parts and supplies. The clerk typist maintains the storeroom and controls access to it.

All storeroom items are numbered and listed in a storeroom catalog. The materials are stored on shelves and in bins. Their location is noted in the storeroom catalog.

To maintain an inventory of each item, a card file is used. This card file has an index card for each item and the cards are filed by item number. A sample index card is shown in Figure No. 27. As items are withdrawn from stock, a storeroom withdrawal slip is completed. The clerk typist revises the index

LARGE FACILITY

supplies. The work orders are then filed and become a history of work accomplished.

Comprehensive preventive maintenance procedures and checklists have been developed for each item of equipment. These procedures are based upon the manufacturers' recommendations. These procedures are bound into a maintenance manual and each operating section has a copy of the manual. The procedures are indexed and referenced to the equipment number. As a procedure is needed, a copy of the procedure is made and given to the mechanics who are to perform the PM tasks.

Storeroom and Inventory System

The storeroom catalog is maintained on the computer. The computer printout lists item number, description, vendor information, cost data, location in the storeroom, maximum and minimum quantities and reorder point. The storeroom catalog printout is placed in a binder for easy use in the storeroom.

The storeroom clerk issues supplies using a storeroom ticket such as the sample shown in Figure No. 28. The clerk will record the information from the storeroom ticket on the inventory form for the equipment item. Items considered as consumables do not require withdrawal slips. The record card is used to maintain information on quantities consumed. The clerk will inventory these items periodically to determine when reorder is required. The inventory system is

EXAMPLE MAINTENANCE MANAGEMENT SYSTEM
(Continued)

SMALL FACILITY

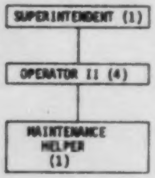
by the superintendent to keep the index card file up to date. The withdrawal slips are maintained in a file as a record of items withdrawn from stock.

Items considered as consumables do not require withdrawal slips. The superintendent inventories these items periodically and updates the inventory cards to determine when reorder is necessary.

When the quantity in stock drops to the reorder point, the superintendent provides a list of items, descriptions, and quantities to the municipal purchasing department to initiate reorder of supplies.

Maintenance Personnel and Organization

The following is a sample organizational chart for a small plant. The number in parentheses identifies the number of employees for each job title:



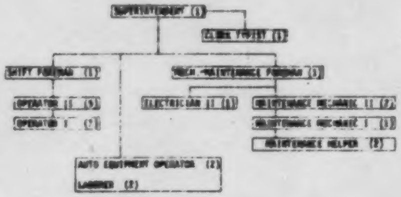
MIDDLE SIZE FACILITY

cards with information obtained from the withdrawal slips. The withdrawal slips are placed in a permanent file for a record of supplies consumed. Figure No. 28 shows a sample withdrawal slip. Items considered as consumables do not require withdrawal slips. The inventory card is used to maintain a record of usage of these items. The clerk typist inventories these items periodically and updates the inventory cards to determine when reorder is necessary.

The clerk reviews the index cards as they are updated to determine if the reorder of supplies is necessary. The items required are listed and given to the maintenance supervisor for his review and to be forwarded to the municipal purchasing department.

Maintenance Personnel and Organization

The following is a sample organizational chart for a middle size facility. The number in parentheses identifies the number of employees for each job title:



LARGE FACILITY

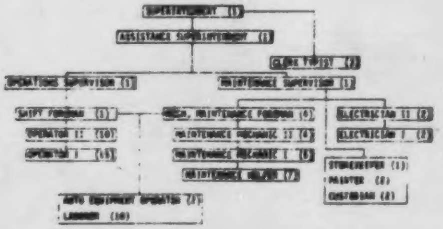
kept up to date by the storeroom clerk. A sample of the inventory card used is shown in Figure No. 27. When the storeroom clerk determines a reorder is required, he prepares the purchase order and forwards it to the city purchasing department. Figure No. 29 is a sample of the type of purchase order used.

Items in the storeroom are located using an aisle and bin designation. This location information is on the storeroom catalog printout.

The storeroom clerk also checks out special tools and keeps information on the cost of general supplies not chargeable to corrective or preventive maintenance work.

Maintenance Personnel and Organization

The following is a sample organizational chart for a large facility. The number in parentheses identifies the number of employees for each job title:



EXAMPLE MAINTENANCE MANAGEMENT SYSTEM
(Continued)

SMALL FACILITY

The superintendent does not have an assistant. The second and third shift have only an Operator II on duty.

On the day shift, the superintendent will review operations and maintenance work. The Operator II, in addition to normal operations and maintenance tasks, assigns maintenance tasks to the maintenance helper.

The small plant, because of its limited maintenance capability, must contract out electrical repairs and major mechanical repairs.

The small plant depends on outside sources for training courses to upgrade their staff. The state sponsored operator training schools and short courses sponsored by the Environmental Protection Agency are used to meet the plant's training needs.

The operators must perform maintenance tasks, clerical duties, and record keeping in addition to their normal operating tasks. The superintendent follows operations and maintenance closely to help in planning and scheduling work.

MIDDLE SIZE FACILITY

The superintendent has responsibility for overall plant operations and maintenance. The maintenance foreman is responsible for maintenance planning and scheduling and reviewing maintenance tasks to be accomplished. The clerk typist is responsible for recording maintenance information in the equipment record system and maintaining the storeroom and inventory system. The maintenance mechanics perform the preventive and corrective maintenance tasks. The operations section only performs the minor maintenance required during the normal operation of the equipment.

The maintenance foreman continuously reviews his maintenance staff and provides training to upgrade their qualifications. Maintenance men are sent to short courses or take correspondence courses offered by the State and Federal Water Pollution Control Agencies.

The superintendent and mechanical maintenance foreman review all preventive and corrective maintenance tasks with respect to staff size and capabilities. They then decide what tasks must be contracted to outside repair services. Arrangements are made with private contractors or service agencies to perform all tasks beyond the capability of facility personnel.

LARGE FACILITY

The superintendent has responsibility for overall plant operations and maintenance. The maintenance supervisor is responsible for maintenance operations and keeps the superintendent informed of the status of the maintenance program. The maintenance supervisor is responsible for reviewing maintenance tasks and planning and scheduling the work. The records clerk maintains equipment records and prepares the work orders.

The storeroom clerk maintains the storeroom and inventory system, keeps all related records and initiates purchase orders. The Electrician II aids in planning and scheduling electrical tasks. The operation section correlates operations with required maintenance tasks and only performs the minor maintenance required during the normal operation of the equipment.

The maintenance foremen continuously review the maintenance operations and report to the maintenance supervisor. They also review the maintenance staff and recommend training to upgrade their qualifications. The facility management provides training courses for the maintenance personnel at the facility in addition to courses provided by high schools, colleges, and State Water Pollution Control Agency. The maintenance supervisor reviews all preventive and corrective maintenance tasks with respect to staff size and capabilities. A list of tasks which must be contracted to outside repair service has been prepared. Arrangements have been made with private contractors

EXAMPLE MAINTENANCE MANAGEMENT SYSTEM
(Continued)

SMALL FACILITY

Costs and Budgets for Maintenance Operations

The cost information from the equipment record system, work orders, storeroom inventory cards and the maintenance man-hours are used to develop the maintenance budget. To aid in determining maintenance man-hours, a cost coding system breaks an employee's eight hour shift down into time spent performing various types of work. The coding system uses 01 as the charge code for normal operations, 02 for preventive maintenance and 03 for corrective maintenance. The municipal accounting department maintains these man-hours and provides cost summaries to the superintendent. He uses these totals to determine if maintenance man-hours are excessive and to compare corrective maintenance man-hours to preventive maintenance man-hours. This helps the superintendent to determine if his preventive maintenance program is being performed satisfactorily. (NOTE: See Section VIII. Costs and Budgets for Maintenance Operations, for additional information on maintenance budget preparation.)

The user of this manual should review his particular plant's requirements and develop his own system using this example as a guide.

MIDDLE SIZE FACILITY

Costs and Budgets for Maintenance Operations

The superintendent and maintenance supervisor review the cost information in the equipment record system, work orders, storeroom inventory cards, and the maintenance man-hours to help them develop a maintenance budget. To aid in determining maintenance man-hours, a cost coding system breaks an employee's eight hour shift down into time spent performing various types of work. The coding system uses 002 for sick leave, 001 for vacation, 003 for holidays, 004 series numbers for normal operation tasks, 005 series for PM work and 006 series for corrective maintenance work. Only breaking the man-hours between operations and maintenance is sufficient for budget purposes, but the breakdown on maintenance man-hours helps the supervisor in establishing time requirements for performing repetitive maintenance tasks. In addition, he uses these man-hours and cost summaries to determine if maintenance man-hours are excessive and to compare corrective maintenance man-hours to preventive maintenance man-hours. This helps the superintendent determine if his preventive maintenance program is being performed satisfactorily. (NOTE: See Section VIII. Costs and Budgets for

LARGE FACILITY

and service agencies to perform all tasks beyond the capability of the facility staff.

Costs and Budgets for Maintenance Operations

The sources of information on maintenance costs include computer files, storeroom cards, work orders and maintenance contracts. The maintenance supervisor assists the superintendent in developing a maintenance budget. The computer has the cost data on preventive and corrective maintenance on file, and this information is used in evaluating maintenance work.

In addition, maintenance costs for an individual item of equipment can be obtained from the computer to determine if maintenance costs are excessive in relation to original cost.

To aid in determing maintenance man-hours, a cost coding system breaks an employee's eight hour shift down into time spent performing various types of work. A sample coding system provides codes as V01 for vacation, S02 for sickness, H03 for holidays, N04 series for normal operations tasks, N05 series for preventive maintenance and N06 series for corrective maintenance work. Breaking the man-hours between operations and maintenance is sufficient for budget purposes, but the breakdown on maintenance man-hours helps the superintendent and

EXAMPLE MAINTENANCE MANAGEMENT SYSTEM
(Continued)

SMALL FACILITY

MIDDLE SIZE FACILITY

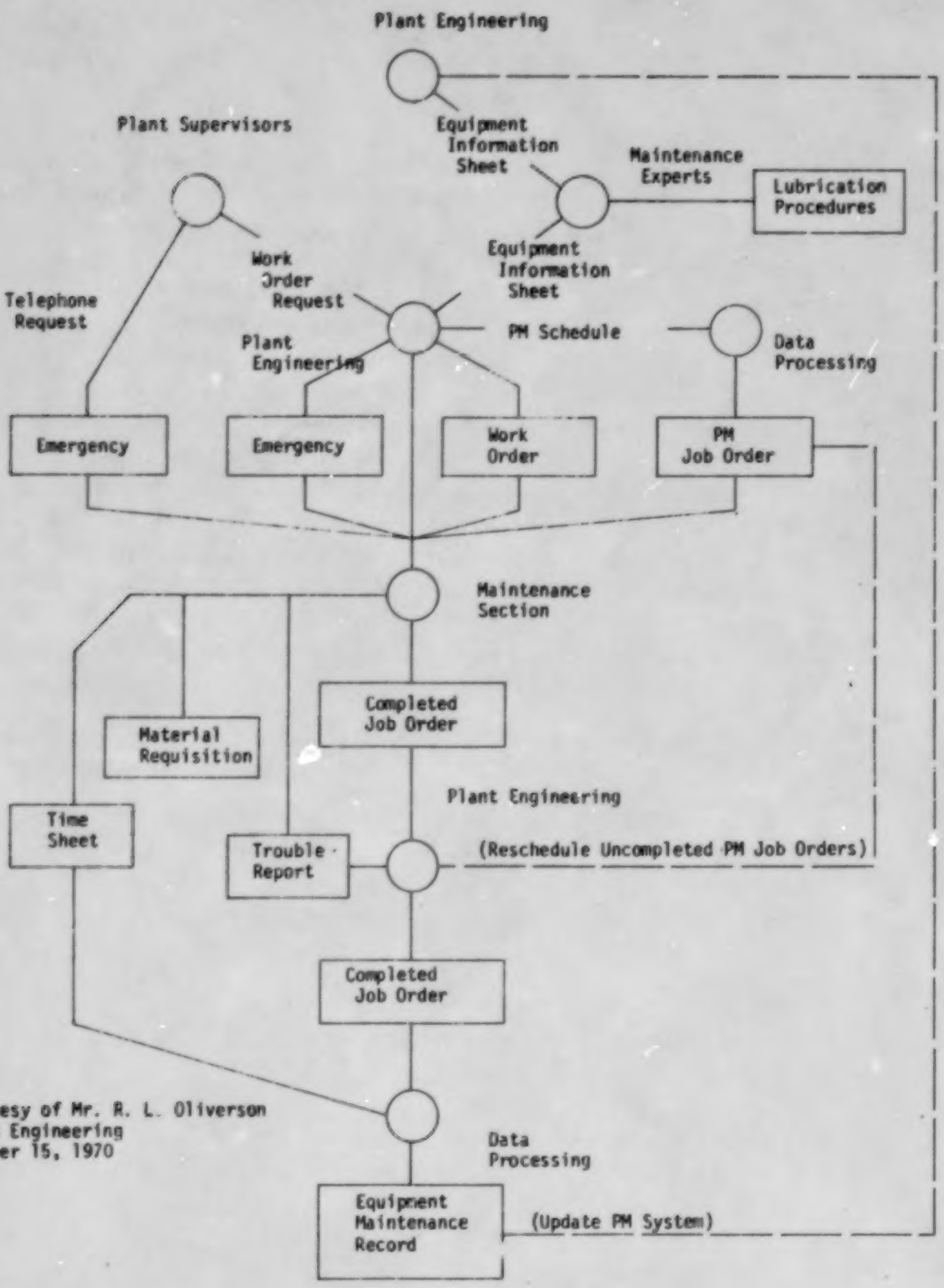
Maintenance Operations, for additional information on maintenance budget preparation.)

A person developing a system for a middle size plant should review his particular plant's requirements and develop his own system using this example as a guide.

LARGE FACILITY

maintenance supervisor establish time requirements for performing repetitive maintenance tasks. (NOTE: See Section VIII, Costs and Budgets for Maintenance Operations, for additional information on maintenance budget preparation.)

A person developing a system for a large plant should review his particular plant's requirements and develop a system compatible using this example as a guide.



Courtesy of Mr. R. L. Oliverson
Plant Engineering
October 15, 1970

Information Flow in
Computerized Maintenance Management System

T10.2.19

SECTION X

MAINTENANCE MANAGEMENT SYSTEM EVALUATION GUIDELINES

This section is to aid persons developing maintenance management systems by providing a checklist for evaluating a proposed system and to aid treatment plant management in evaluating an existing maintenance management system. The evaluation guidelines are broken down into the five basic maintenance features considered essential to a maintenance management system. A maximum of two hundred (200) points have been allotted to each feature, thus a maximum score of one thousand (1000) points is possible. In reviewing a system, the evaluator must remember these guidelines apply to all types and sizes of treatment plants. Due to the range of plant sizes and their complexities, no minimum passing score has been given. The purpose of these guidelines is to aid in locating problem areas so they may be corrected or improved. An individual using these evaluation guidelines will generally find the maintenance system he is analyzing does possess most of the features outlined in the Guidelines. However, there will probably be many qualifications accompanying each positive response to the questions in the Guidelines. This is true because the features of many maintenance systems are either incomplete or are incapable of performing their intended function. Each question in the Evaluation Guidelines should be carefully weighed and given a rating commensurate with the feature's ability to perform its role in the total maintenance management system.

EQUIPMENT RECORD SYSTEM

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
1. Do you have an equipment numbering or other identification system to aid in locating and identifying all major items of equipment?	20	
2. Do you have a system for maintaining nameplate data and other essential information on all major equipment items within the treatment system?	50	
3. Does your maintenance record system provide for listing preventive maintenance (PM) tasks, giving their frequency and recording the PM work performed?	30	

Source: *Maintenance Management Systems for Municipal Wastewater Facilities*, Section X, U. S. Environmental Protection Agency, Washington, D.C. (October, 1973)

EQUIPMENT RECORD SYSTEM
(CONTINUED)

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
4. Does your maintenance record system provide for recording corrective maintenance work performed?	20	
5. Does your maintenance record system provide for recording such information as maintenance man-hours, spare parts or components used in repair and name of individual performing each job?	30	
6. Does your maintenance record system provide for recording all maintenance related costs and can these costs be readily compiled for use in maintenance budget preparation?	30	
7. Are miscellaneous maintenance related documents such as as-built drawings, construction specifications and photos, shop drawings and manufacturers' literature properly filed and indexed and readily available to maintenance staff?	20	
TOTAL	200	

PLANNING AND SCHEDULING

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
1. Is some form of schedule chart or priority list provided to assist maintenance supervisors in controlling maintenance tasks?	20	
2. Do you plan and schedule preventive maintenance (PM) tasks for all major equipment items within the treatment system?	30	

PLANNING & SCHEDULING
(CONTINUED)

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
a. Are PM frequencies based upon manufacturers' recommendations and by inspection?	10	
b. Does the existing maintenance organization permit the proper scheduling of required PM and take into account the corrective maintenance demands on the maintenance force?	10	
3. Are potential corrective maintenance tasks adequately considered in maintenance planning?	20	
4. Do you have a work order system that satisfies the treatment system's maintenance requirements?	30	
5. Are manpower management techniques used effectively to obtain maximum utilization?	30	
6. Do you have some form of labor standards to assist in preparing accurate work estimates for repetitive maintenance jobs?	30	
7. Have you contracted for maintenance tasks beyond the capability of your staff and determined the availability of this support?	20	
TOTAL	200	

720

STOREROOM AND INVENTORY SYSTEM

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
1. Have you provided a storeroom or storage area to assist in controlling the flow of spare parts, components and maintenance supplies?	40	
2. Have you reviewed manufacturers' recommendations and studied each major equipment item's maintenance requirements to determine what maintenance items should be maintained?	40	
a. Have you developed a system to monitor quantities of all maintenance items kept in stock?	20	
b. Have you established minimum and maximum quantities for all maintenance items kept in stock?	20	
c. Do you have a purchase order system that adequately controls the procuring of maintenance items?	20	
3. Do you have system for locating a given item in the storeroom?	20	
4. Do you have a catalog or index system to assist in identifying and locating a given item in the storeroom?	20	
5. Do you have a storeroom ticket or withdrawal slip to use when maintenance items are taken from stock?	20	
TOTAL	200	

T10.2.23

MAINTENANCE ORGANIZATION & PERSONNEL

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
1. Do you have a maintenance organization chart that satisfies treatment system requirements?	30	
2. Is your maintenance organization chart reviewed and updated as required?	20	
3. Do you have job descriptions for each job title within your maintenance organization?	30	
4. Are job descriptions kept up to date and made available to maintenance personnel as required?	20	
5. Prior to initiating any program to correct deficiencies in a maintenance job, is a thorough analysis of this job performed?	50	
6. Do you have a maintenance training program that satisfies the maintenance objectives of the treatment system?	50	
TOTAL	200	

COST AND BUDGETS FOR MAINTENANCE OPERATIONS

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
1. Are maintenance costs broken down by maintenance categories such as preventive maintenance, corrective maintenance and major repairs or alterations?	50	
2. Do you have a system of cost codes or charge numbers for allocating labor and materials to specific maintenance jobs?	40	

COST AND BUDGETS FOR MAINTENANCE OPERATIONS
(CONTINUED)

EVALUATION GUIDELINES	MAX. RATING	YOUR RATING
3. Do you have a system for recording the maintenance cost history of all major equipment items?	30	
4. Do you have a system for compiling cost information for use in budget preparation and maintenance cost studies?	50	
5. Do you have a system for recording contract maintenance costs so they can be used in preparing maintenance budgets?	30	
TOTAL	200	

Persons using these Evaluation Guidelines should follow up the evaluation with a review of the areas receiving the lowest ratings. It should be remembered that an apparent weak area may be due to another system feature performing poorly and pulling the weak area down.

The questions in the Evaluation Guidelines are grouped into the five basic maintenance features. Individuals can review the section of the manual which discusses each basic feature when they find deficiencies in the maintenance system they are analyzing. The information contained in the manual should assist persons in correcting the weaknesses in their maintenance management system.

It should be recognized that several of the questions in the Evaluation Guidelines deal with items that are absolutely essential to the success of any maintenance management system. These critical items include an equipment identification system, planning and scheduling preventive maintenance tasks, control of spare parts and supplies, and a system for preparing maintenance budgets. Maintenance management systems that receive low ratings in any of these critical areas should be considered deficient and appropriate corrective actions taken.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 10: Management Behavior

Lesson 3: Managerial Functions

Lesson 3 of 3 lessons Recommended Time: 50 minutes

Purpose: The wastewater treatment facility manager performs five basic functions: planning, organizing, staffing, directing and controlling. This lesson briefly defines each managerial function and provides the trainee a "management audit" form which can be used by wastewater treatment managers as a self-appraisal of their management programs. Case history problems are analyzed to emphasize the importance of management evaluation to overall wastewater treatment facility troubleshooting.

Trainee Entry Level Behavior: Trainees should have achieved the learning objectives specified for Unit 10, Lesson 2, before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. From memory, list and describe the five functions of management and explain why each is important to wastewater treatment plant operations.
2. Using the management audit included in the *Trainee Notebook*, explain how the troubleshooter can assist a wastewater treatment facility manager evaluate the plant's management programs.
3. Demonstrate an ability to analyze a management related problem and advise the wastewater facility manager on management related issues by analyzing two case history problems.

Instructional Approach: Illustrated lecture, problem solving and class discussion.

Lesson Schedule: The 50 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 10 minutes	The Managerial Functions
10 - 15 minutes	The Management Audit
15 - 30 minutes	Case History Problem Number 1
30 - 45 minutes	Case History Problem Number 2
45 - 50 minutes	Summary

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, page T10.3.1, "The Managerial Functions."
2. *Trainee Notebook*, pages T10.3.2 - T10.3.3, "The Management Audit."
3. *Trainee Notebook*, pages T10.3.4 - T10.3.9, "Management Audit Checklist."
4. *Trainee Notebook*, page T10.3.10, "Case History Problem 1."
5. *Trainee Notebook*, page T10.3.11, "Case History Problem 2."
6. *Trainee Notebook*, page T10.3.12, "References."

Instructor Materials Used in Lesson: Instructor Notebook, pages 10.3.1 - 10.3.5, Unit 10, Lesson 3.

Instructor Materials Recommended for Development: None

Additional Instructor References: Supervisory Management in the Water/Wastewater Field, Michigan State University, East Lansing, MI (1977).

Classroom Set-Up: As specified for Unit 10, Lesson 1.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
I. The Managerial Functions (10 minutes)	
A. Ask class to list the functions of the manager.	Have one trainee go to the chalkboard and record functions identified by the class.
B. After the class had identified managerial functions and the chalkboard listing is complete, group the class listings into the following five categories: 1. Planning 2. Organizing 3. Staffing 4. Directing 5. Controlling	
C. Using *Trainee Notebook* page T10.3.1, define each managerial function and relate the function to wastewater treatment plant operation and maintenance.	Refer class to *Trainee Notebook*, page T10.3.1, "The Managerial Functions."
II. The Managerial Audit (5 minutes)	
A. Refer class to *Trainee Notebook*, pages T10.3.2 - T10.3.9, "Management Audit."	Refer to *Trainee Notebook*, pages T10.3.2 - T10.3.9, "Management Audit."
B. Have class scan the audit form noting its organization by managerial function.	
C. Discuss with class how the Management Audit form could be used in troubleshooting: 1. Provide to plant manager and assist him/her in performing a self-evaluation of management programs at the plant. 2. With the plant manager, identify weak points in present management system. 3. With the plant manager, develop a plan to correct weaknesses.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
4. Assist plant management to implement its program of self-improvement in management related areas.	
D. Management Training	
1. Numerous management workshops are available but many wastewater treatment managers, particularly at smaller plants, have no formal management training.	
2. Recommend the self-study course "Supervisory Management in the Water/Wastewater Field," available from Michigan State University as a good first course in management and supervision for wastewater operators.	
III. Case History Problem 1 (15 minutes)	
A. Refer to *Trainee Notebook*, page T10.3.10, for the problem statement.	Refer to *Trainee Notebook*, page T10.3.10, "Case History Problem 1"
B. Have each work group spend about 5 minutes analyzing the problem.	
C. Have groups report their findings.	Encourage class discussion. Use about 10 minutes for discussion.
D. Briefly summarize the class findings. (Note: There are no right or wrong answers - just good and better answers.)	
IV. Case History Problem 2 (15 minutes)	
A. Refer to *Trainee Notebook*, page T10.3.11, for the problem statement.	Refer to *Trainee Notebook*, page T10.3.11, "Case History Problem 2"
B. Have each work group spend about 5 minutes analyzing the problem.	
C. Have groups report their findings	Encourage class discussion. Use about 10 minutes for discussion.
D. Briefly summarize the class findings. (Note: There are no right or wrong answers - just good and better answers.)	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES

V. Summary and Discussion (5 minutes)

A. Use any remaining time for general discussion on the importance of management evaluation and troubleshooting in improvement of treatment plant performance.

B. If time allows, pose the following questions to the class for discussion:

1. What do you do and say to the client when you are called in to troubleshoot a problem on which other consultants have been involved?
2. What do you do or say when you are called in to troubleshoot a problem that is an obvious design problem in a plant which your firm has designed?

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 10: Management Behavior

Lesson 3: Managerial Functions

Trainee Notebook Contents

The Managerial Functions T10.3.1

Management Audit T10.3.2

Management Audit Checklist T10.3.4

Case History Problem 1 . . . . T10.3.10

Case History Problem 2 . . . . T10.3.11

References T10.3.12

The Managerial Functions

Planning

"Planning is the managerial function which consists of determining in advance what should be done." Planning in the water/wastewater field takes many forms - from deciding how many chemicals to order, to how to obtain additional revenue, expand service areas, conduct public information programs or meet manpower requirements. The manager must decide what is going to be done, when the tasks will be undertaken and when they are expected to be completed.

Organizing

"Organizing means to answer the question, 'How will the work be divided and accomplished.'" It is usually within the organizing function that the supervisor must delegate authority. Organizing in the water/wastewater field includes setting up the various shifts of duty, and establishing engineering, operating, maintenance, accounting, personnel, clerical and other activities.

Staffing

"Staffing is the managerial function of recruiting new employees and determining whether there are enough qualified employees to fill the available positions." Note the word "qualified". This encompases a variety of training situations. It also includes job specifications, evaluation procedures, promotion and replacement, often within certain professional registration and certification requirements.

Directing

"The directing function includes guiding, teaching, motivating and supervising subordinates." The previous function touched upon the training of employees for particular jobs. This function tends to dwell on the preparation of employees to perform certain tasks while directing tends to encourage those same workers to perform those tasks better and more efficiently - and to continue to do so, often within local, state and federal limits. Among the challenges utilities face is to improve working conditions, build a better safety record, contribute to the public health and improve the environment.

Controlling

"Controlling involves those activities that are necessary to make certain that objectives are achieved as planned." This brings us back to the original function of planning and completes the circle. Controlling activities in the water/wastewater field include: direction and scope of utility system expansion, number of employees, inventory levels, employment of outside forces.

Source: *Supervisory Management in the Water/Wastewater Field*, Michigan State University and U. S. Environmental Protection Agency, 1977

Management Audit

Introduction

Before management problems can be alleviated, they must be identified. "What are our system needs?" This is the question each utility-management team should be asking, according to a statement in the May, 1971, special issue of Willing Water. The special issue further states that recognition and acceptance of these needs is a prime prerequisite of programs that will provide further improvements in service and quality. As part of the Action Now program, AWWA developed a self-evaluation questionnaire to assist in appraising the technical needs of a utility. Michigan State University, through the AWWA-WPCF-spondored Institute for Water and Wastewater Utility Management, developed a self-evaluation audit format that will assist a utility in appraising management-related problems. Use of a practical management-audit format should provide benefits to water and wastewater utilities.

Can audit procedures define management problems? There are several examples of the practical application of the audit approach to management. Everyone is generally familiar with the accounting audit, which checks actual cost records against the accepted standard procedures. Auditing was for many years associated with and considered a part of accounting only. The essential purpose of the audit was to provide an examination by a firm of outside auditors to determine the financial condition and to uncover errors and fraud. Today modern management in business, with its greater complexities, requires a close check on the entire scope of management control and performance. The objective is to achieve the most effective and efficient administration of the total business operation with continuous improvement in policies and procedures. The management audit can be defined as:

> A comprehensive and constructive examination of an organizational structure of a company or its components such as division or department, its plans and policies, its financial control, its methods of operation and its use of human and physical facilities.

The objective of the management audit is to reveal defects or irregularities in any of the elements of the organization under study. The purpose of a management audit is to achieve:

- Reduction of waste and deficiencies
- Improved methods
- Better means of control
- More efficient operations
- Greater use of human and physical facilities

Conclusions

The water and wastewater utility industry has recognized the management needs of the industry for many years. However, for various reasons individual utilities have not defined their own particular management deficiencies. Several factors suggest that this situation will be corrected. First and foremost is the increased interest and effort from within the industry in being professionals in management skills and in the performance of their utility operations. The major associations also have clearly demonstrated increasing interest and effort in management development for the industry. Second, there are pressures that will force increasing interest in the recognition and solution of management deficiencies in the industry. These include but are not limited to: (1) the transition from construction to operations as more new plants come on line; (2) greater pressure by governmental agencies for some form of certification at all levels, possibly including supervision and management; and (3) greater involvement in the review of utility performance by public-interest groups. There is no easy way to recognize, define and solve management problems, but a management-audit procedure will be of assistance to a utility management team.

Management Audit Checklist

A. Objectives

1. Does your group have defined objectives?
2. Have written objectives been prepared for the group?
3. Are the objectives distributed to all subordinates?
4. Do the subordinates understand all of the objectives?
5. Are the reasons ("why") for the objectives understood?
6. Are the objectives reviewed and updated at least twice per year?
7. Do subordinates participate in setting the objectives?
8. Can you and your supervisor(s) measure and judge the level to which the objectives are achieved?

B. Planning

1. Do you plan for
   a. a week?
   b. a day?
   c. one shift?
   d. a month?
   e. longer than a month?
2. Are you informed concerning the long range plans and objectives of the organization?
3. Are your subordinates fully informed of the plans for your group or department?
4. Do you have policies, procedures and methods written to assist in guiding you in your responsibilities to carry out top management objectives?
5. Do you utilize a budget stated in time, material, money or other units?
6. Do you assist in preparation of the budget?
7. Are results compared with the budget to study and analyze the variations?
8. Do you make a projection of the future to forecase the equipment, space, material, etc. which your group will require?
9. Do you make a projection to forecast the number and qualifications of employees?
10. Are you familiar with the trends in wages, fringe benefits and costs?

B. Planning (continued)

11. Do you check with available staff specialists to prepare forecasts?

12. Do you consider the tactics of timing, joint action and approach to implementing changes in developing your plans?

13. Do your plans consider utilization of resources:

    a. tools and equipment?
    b. work methods and processes?
    c. space?
    d. materials and supplies?
    e. supervisory time?
    f. employee time?
    g. full utilization of work force?

14. Do you attempt to make the new employee's transition as smooth as possible?

15. Do you do on-the-job training yourself and/or assign this duty to a qualified subordinate?

16. Are subordinates encouraged to take advantage of training opportunities?

17. Do you formally evaluate your subordinates at least annually?

18. Is a formalized system of evaluation used (a merit rating or performance appraisal system)?

19. Is an appraisal form utilized for performance evaluation?

20. Do you personally perform an appraisal interview with each subordinate?

21. At the close of the interview do you make certain that the employee has a clear understanding concerning his/her rating?

22. Are employees generally promoted from within the group?

23. Are seniority, merit and ability considered as criteria for promotion?

24. Do you attempt to ensure that wages paid in your group are equitable

    a. internally within the group?
    b. externally with the going rate for similar jobs in the organization and community?

25. Do you review wage and salary information collected by personnel and/or yourself?

C. Organization

1. Are the jobs of the group clearly defined?

2. Are the jobs assigned?

3. Is authority adequately delegated?

4. Are two-way lines of communication established between yourself and your subordinates?

C. Organization (Continued)

5. Does each employee have a single immediate supervisor?
6. Do you supervise a reasonable number of employees?
7. Does each employee know what standards are expected of him/her?
8. Are you inclined to assign the more difficult tasks to the most capable employees?
9. Is your group attached to the organization in a line capacity? in a staff capacity?
10. Is your position described in an organization manual?
11. Are activities grouped by function?
12. Do you have a subordinate who is currently qualified to take over your position?
13. If you do not have a qualified understudy for your position, are you training someone as an understudy?
14. Have organization charts, manuals and position descriptions been prepared?
15. Do you know the leader of the informal organization within your span of control?
16. Do you actively work with and build good relations with the informal leader?

D. Staffing

1. Have you defined the specific qualifications for employees hired for your group?
2. Do you interview, select and hire from candidates the individual you consider most appropriate for a particular position?
3. Are all new employees assigned to specific jobs?
4. Is each new employee introduced to the specific details of his/her job, rules, hours, etc.?
5. Do you follow up and check on each employee's performance?
6. Do you discipline your subordinates?
7. Do you discharge a subordinate if necessary?
8. Are you responsible for determining the need for employees in your department or group?
9. Do you participate in writing the job descriptions for your group?

D. Staffing (continued)

10. Do you participate in writing the job specifications required of an employee for each job category?

11. Have you utilized the directive interview technique?

12. Have you utilized the non-directive interview technique?

13. Do you prepare for an employment selection interview by:

    a. acquainting yourself with background information on each applicant?
    b. preparing a schedule or plan for the interview?
    c. selecting a proper location for the interview?
    d. trying to place the applicant at ease?
    e. generating two way communication?
    f. attempting to eliminate your personal preferences and prejudices?
    g. being as honest as possible with each applicant about the selection decision?

E. Directing

1. Do all directives or orders come only from you as the supervisor?

2. Are all of your directives:

    a. reasonable in terms of being able to accomplish the task?
    b. understood by the subordinate?
    c. issued in appropriate tone and words to stimulate willing and enthusiastic acceptance?
    d. compatible (consistent) with the purposes and objectives of the organization?
    e. specify time limit to complete the task?

3. Do you generally choose autocratic, close supervision giving direct, clear and precise orders to subordinates with detailed instructions?

4. Do you generally consult with the employee concerning a problem before making a decision and issuing a directive?

5. Do you allow the employee to work out details of an assigned task?

6. Are the reasons behind your directives explained to subordinates?

7. Do you help your subordinates understand the need and impact of change before the change is implemented?

8. Do subordinates share in decisions involved in implementing change?

9. Are you alert to the factors influencing morale:

    a. external (sickness in the family, hobbies, etc.)?
    b. internal (job security, appreciation for a job well done)?

E. Directing (continued)

10. Are your subordinates reminded of how significantly they contribute to overall objectives?

11. Do you generally act toward your employees as a leader who has the situation well in hand and can rely upon employees to help correct the situation if something goes wrong?

12. Do you attempt to measure morale through:

    a. observation (levels of productive efficiency, tardiness and absenteeism, accident and safety records, etc.)?
    b. morale and attitude surveys?

13. Are new rules introduced with an explanation to subordinates what is expected of them and why the rules are needed?

14. Do you follow the rules that you expect subordinates to observe?

15. Is your disciplinary action taken with sensitivity and sound judgment to discipline subordinates as appropriate?

16. Is a thorough investigation conducted before taking disciplinary action?

17. Is disciplinary action taken in private with the employee involved?

18. Do you in general utilize the ideas of progressive disciplinary actions as follows:

    a. informal talk?
    b. oral warning or reprimand?
    c. written or official warning?
    d. disciplinary layoff?
    e. demotion?
    f. discharge?

19. In taking disciplinary action, do you follow the "hot stove rule" attempting to begin the disciplinary process as soon as you notice the violation, warn subordinates in advance of the consequences of violations, applying discipline consistently and impersonally?

20. Does each subordinate have the right to appeal disciplinary action?

F. Controlling

1. Are controls available to assist in correcting deviations from established standards as soon as possible so as to minimize the time lag between results and corrective action?

2. Do you have enough familiarity with the jobs of your subordinates to determine which jobs should be observed daily, weekly, monthly, etc.?

3. Are the controls utilized economical and adequate for the jobs under your responsibility?

F. Controlling (Continued)

4. Are the controls utilized flexible to adjustment if warranted?
5. Do you follow the three basic steps essential for control:
    a. set standards for measuring performance?
    b. checking on performance versus standards or goals?
    c. take corrective action for variations from standards?
6. Is a budget used in your control process?
7. Do you participate in making the budget for your group?
8. Is there some flexibility in the budget through regular budget reviews?

G. Labor Relations

1. Are you permitted to express your opinion in reference to labor negotiations?
2. Are you kept informed about the course of labor negotiations?
3. Do you keep records that would be useful in labor negotiations (incidents, absenteeism, productivity, etc.)?
4. Do you thoroughly understand the labor agreement?
5. Do you consult with higher management on labor clauses for interpretation?
6. Is appropriate action taken if a subordinate does not comply with contract provisions?
7. Can you develop a proper relationship and communication with the union steward?
8. Do you observe the following check list for grievances:
    a. be available to the shop steward and to any aggrieved employee?
    b. listen to the grievance?
    c. do not become angry?
    d. summarize what has been presented and define what is actually the problem?
    e. get the facts related to the grievance?
    f. check the labor agreement to determine the the contract has been violated?
    g. settle the grievance as soon as possible?
    h. consider consequences of the settlement to make certain that the decision is consistent?
    i. be as consistent as possible explaining any exceptions?
    j. answer each grievance in a straight-forward, reasonable manner?
    k. adjust grievances at the first step of the grievance procedure if possible?
    l. keep records on all settlements?

Case History Problem 1

Bill Bender, Chief Operator at the South Plant of Eastmoreland Sanitary District, started with the District twenty years ago. The plant, as a result of industrialization and suburban sprawl, has been upgraded twice since then from a primary plant to activated sludge plant in 1960, and to tertiary treatment with nitrification and phosphorous removal with chemical addition in 1974. When Bill started, he had only two assistants and, as a result, handled most of the laboratory and maintenance work himself. Now he has a staff of 14 employees, three of which have the highest certification levels attainable in the state. Bill is a very conscientious chief operator who prefers to do as much of the work as possible himself instead of assigning duties to his subordinates. He spends most of his time performing the testing required for NPDES monitoring at the expense of process control and maintenance.

In the last year, there have been numerous complaints from residents concerning odors from the plant and two letters from the state concerning non-compliance of the effluent with NPDES requirements.

Fred Meaney, Manager of the Sanitary District, feels that much of the problem at the plant centers around Bill Bender. Fred has talked to Bill and asked him to assign more duties and delegate more authority to his subordinates. Also, he suggested trying some of the ideas of the younger operators. Bill listens, but doesn't take any follow-up action. Meanwhile, things at the plant keep getting worse. Fred Meaney feels that he must take some type of action to straighten things out at the South Plant. However, he doesn't want to fire Bill who is 61 years old and a close friend. Since you're the consultant for the District, Fred comes to you for advice.

1. Identify which type of management functions apply in this case.

2. Identify any appropriate items that appear on the Management Audit Checklist.

3. What advice would you give Fred Meaney?

Discuss this in your group and prepare to discuss it with the class.

Case History Problem 2

As an Operations Specialist, you are in the field performing a quarterly operation and maintenance inspection of the 10 MGD activated sludge plant for the Council of the City of Martinsburg. You're touring the facility with Bob Whitefish, the Superintendent. The plant employs 30 people. During the tour, you see four employees eating their lunch at the bench next to the vacuum filter. Bob complained to you about this and stated that he wished the employees would eat in the lunch room. Another complaint Bob had is that even though the workers are supplied with uniforms at no cost, they continue to wear all types of sportswear to work. Another problem that irritated Bob was the fact that employees taking sick leave were not compelled to prove illness with a note from their physician upon return to work.

Furthermore, Bob stated that these problems weren't particular to the wastewater plant. The street foreman and water superintendent had indicated to him that they had the same problems. Bob asks you to request in your inspection report that the Mayor institute city policies concerning the above problems.

1. Identify the management function(s) applicable in this case.

2. Identify the appropriate items from the Management Audit Checklist.

3. Is it your responsibility to bring the matter to the Mayor's attention?

4. Is it the Mayor's responsibility to dictate policy in these matters or should the individual supervisors be making these decisions?

REFERENCES

1. American Management Association, *Supervisory Effectiveness - A Home Study Course.*

2. Bittel, *What Every Supervisor Should Know*, McGraw-Hill.

3. *Emergency Planning for Municipal Wastewater Treatment Facilities*, U. S. Environmental Protection Agency.

4. *Estimating Staffing for Municipal Wastewater Treatment Facilities*, U. S. Environmental Protection Agency, Office of Water Programs Operations, 1973.

5. *Guidebook for Employers*, Equal Employment Opportunity Commission, Affirmative Action and Equal Employment.

6. Hayes, R. B., *Operator's Guide to Management and Supervision*, STRAAM Engineering, Inc., Portland, Oregon, 1975.

7. *Handy Reference Guide to the Fair Labor Standards Act*, U. S. Department of Labor, Washington, D.C.

8. *Maintenance Management Systems for Municipal Wastewater Facilities*, U. S. Environmental Protection Agency, Office of Water Programs Operations, 1973.

9. *Supervisory Management in the Water/Wastewater Field*, Michigan State University and U. S. Environmental Protection Agency, 1977.

10. Water Pollution Control Federation, *MOP 1: Safety in Wastewater Works.*

11. Water Pollution Control Federation, *MOP 10: Uniform System of Accounts for Wastewater Utilities.*

12. Water Pollution Control Federation, *MOP 12: The Public Relations Handbook.*

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Unit 11 of 15 Units of Instruction

Lessons in Unit: 14 Recommended Time: 13½ hours

Instructor Overview of the Unit

Rationale for Unit: Activated sludge processes are among the most widely used secondary treatment processes. The majority of new secondary treatment wastewater treatment plants constructed under the federal grants program incorporate activated sludge processes. Activated sludge treatment plants range from very small "package units" treating a few thousand gallons per day to the largest treatment plants treating in excess of a billion gallons per day. U. S. EPA survey results indicate that activated sludge treatment facilities are more likely to experience performance problems caused by O & M defects than other secondary treatment processes. The troubleshooter, therefore, is very likely to be required to provide assistance at activated sludge plants. Experience has shown that troubleshooting at activated sludge plants can yield dramatic improvements in facility performance if the troubleshooter and operator effectively use the process control flexibility inherent to the activated sludge system. Experience further shows that many operators and technical assistance personnel are inadequately trained in activated sludge process control and problem solving. Thus, this course allocates a substantial portion of instructional time to activated sludge process by developing a sound theoretical basis for activated sludge process control principles and applying these principles to process control and problem solving situations.

Trainee Entry Level Behavior: The trainee should have completed and achieved the learning objectives specified for Units of Instruction 1 and 2 before beginning the *Activated Sludge* unit of instruction.

Trainee Learning Objectives: Upon completion of the Activated Sludge unit of instruction, the trainee will be able to:

1. From memory, state the process objective for the activated sludge system.

2. From memory, describe in qualitative terms the aerobic biological degradation of organic materials, relate the degradation process to the bacterial growth curve, list the principle factors which affect the efficiency of the aerobic biological systems and explain their significance in achieving the process objective.

3. From memory, list the variables in the activated sludge process which can be manipulated by the operator to maintain an optimum environment to achieve the activated sludge process objective and explain how a change in each manipulated variable affects the process.

4. From memory, list and define the parameters which are used to evaluate and control the activated sludge process, list the samples and laboratory tests needed to determine each parameter, list the advantages and disadvantages of each parameter and explain why no single parameter can be used to affect consistent process control.

5. From memory, explain the significance of trend changes in each process control parameter, describe how the process control parameters relate to each other and explain how trend changes in the process control parameters can be interpreted to determine quantitative operator responses in the controllable variables: aeration rate, return sludge flow rate and waste sludge rate.

6. Using the *Trainee Notebook*, class notes and other references, list the most frequently occurring problems in the activated sludge process, list the possible causes for each problem, explain how the process control parameters are used to identify the problem cause and describe the operator responses to correct or prevent each cause.

7. Demonstrate his/her ability to apply the process of troubleshooting to case history problems in activated sludge process control and recommend corrective actions for each case history.

Sequencing and Pre-Course Preparation for the Unit: Unit 11, *Activated Sludge*, is presented as 14 lessons.

Lesson 1: Introduction to Activated Sludge Process Troubleshooting

Recommended Time: 60 minutes

Purpose: Activated sludge wastewater treatment is achieved through a series of complex aerobic biological processes followed by a physical separation (settling) of the activated sludge from the treated wastewater. Many variables, both variables external to and variables internal to the process, affect the overall efficiency of the activated sludge process. The introductory lesson provides a simplified review of activated sludge treatment theory, defines terminology used in the other lessons of the Unit of Instruction, identifies the variables which affect activated sludge process operations and discusses the significance of each variable to activated sludge process operations and troubleshooting.

Training Facilities:

1. Large room, preferably 40' by 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees in groups of four;
2. Instructor table with lectern;
3. Large projection screen (6' x 6' minimum) and chalkboard in front of room and readily seen by all trainees;
4. Easel with pad;
5. 35mm carousel projector with remote control changer at instructor table;
6. At least four empty carousel trays;
7. Overhead projector;
8. Chalk, felt-tip markers and erasers;
9. Six to eight chairs randomly spaced at back and sides of room for visitors.

Pre-Course Preparation:

1. Trainee texts

   Reproduce or purchase and make available at each trainee seating position the following:

   a. *Operators Pocket Guide to Activated Sludge*, Parts I and II, STRAAM Engineers, Inc., Portland, Oregon (1975).

   b. West, A. W., *Operational Control Procedures for the Activated Sludge Process*, Parts I, II, IIIA, IIIB and Appendix, U. S. Environmental Protection Agency, National Training and Operational Technology Center, Cincinnati, Ohio.

   c. West, A. W., "Updated Summary of the Operational Control Procedures for the Activated Sludge Process," U. S. Environmental Protection Agency, National Training and Operational Technology Center, Cincinnati, Ohio

   d. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pp. 55-76, 118-128 and 182-198, EPA 430/9-78-001, Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (January, 1978).

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, page T11.1.1, "Activated Sludge Process Troubleshooting Lesson Objectives."

   b. *Trainee Notebook*, pages T11.2.1 - T11.2.7, "Activated Sludge Process Control Parameters" and "Calculation of Control Parameters."

3. Trainee Handout materials

   Reproduce the following *Trainee Handout* pages and have them available for distribution as called for in the lesson:

   a. None required for Lesson 1.

Instructional Approach: Illustrated lecture with class discussion.

Lesson 2: Process Control Concepts for Activated Sludge

Recommended Time: 50 minutes

Purpose: Activated sludge is a complex aerobic biological wastewater treatment process which is affected by many variables, both variables internal and external to the process. Consequently activated sludge systems require diligent and consistent attention to process control to maintain process blanace and effluent quality. Numerous techniques and strategies for managing activated sludge systems to affect process control have been proposed and used. This lesson reviews the more commonly used process control concepts and discusses their application to activated sludge performance evaluation and troubleshooting. It is essential that the troubleshooter understand and correctly use the various process control tools if he or she is to be effective in providing technical assistance at activated sludge facilities.

Training Facilities:

As specified in Unit 11, Lesson 1.

Pre-Course Preparation:

1. Trainee texts

   As specified in Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, pages T11.2.1 - T11.2.7, "Activated Sludge Process Control Parameters" and "Calculation of Control Parameters."

3. Trainee Handout materials

   Reproduce the following *Trainee Handout* pages and have them available for distribution as called for in the lesson:

   a. None required for Lesson 2.

Instructional Approach: Illustrated lecture and class discussion.

Lesson 3: Activated Sludge Process Variations

Recommended Time: 25 minutes

Purpose: There are several variations of the activated sludge process. The most frequently used process variations are conventional, contact stabilization, extended aeration and step feed activated sludge. The troubleshooter may encounter any of the variations during his/her technical assistance efforts. Hence, the troubleshooter must be familiar with the design and operating characteristics of each process variation.

Training Facilities: As specified in Unit 11, Lesson 1.

Pre-Course Preparation:

1. Trainee texts

   As specified in Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, page T11.3.1, "Activated Sludge Process Variations, Design and Operating Parameters."

3. Trainee Handout materials

   Reproduce the following *Trainee Handout* pages and have them available for distribution as called for in the lesson:

   a. None required for in Lesson 3.

Instructional Approach: Illustrated lecture with trainee discussion.

Lesson 4: Microscopic Evaluation of Sludge

Recommended Time: 25 minutes

Purpose: The predominant species of organisms in activated sludge are indicators of process condition and sludge quality. Periodic microscopic examination of the activated sludge to identify changes in the relative numbers of each species in the sludge population can be used as a guide in process control decision making. This lesson reviews microscopic techniques for examining activated sludge and applies the microscopic observations to process evaluation.

Training Facilities: As specified in Unit 11, Lesson 1.

Pre-Course Preparation:

1. Trainee texts

   As specified in Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, page T11.4.1, "Relative Number of Microorganisms vs. Sludge Quality."

   b. *Trainee Notebook*, page T11.4.2, "Worksheet for Microscopic Examination of Activated Sludge."

3. Trainee Handout materials

   Reproduce the following *Trainee Handout* pages and have them available for distribution as called for in the lesson:

   a. None required for Lesson 4.

Instructional Approach: Illustrated lecture with class discussion.

Lesson 5: Process Control Based on Sludge Settleability

Recommended Time: 50 minutes

Purpose: Activated sludge process treatment depends on producing sludge solids which can be separated from the liquid phase in the final clarifier. The settling characteristics of the mixed liquor suspended solids vary with conditions in the aeration basin and final clarifier. Observation of sludge settling characteristics provides valuable information for determining process adjustments to maintain or improve sludge quality. This lesson describes sludge settling test procedures and discusses the application of settling test data to process control.

Training Facilities: As specified in Unit 11, Lesson 1.

Pre-Course Preparation:

1. Trainee texts

   As specified in Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, pages T11.5.1 - T11.5.8, "Activated Sludge Process Data for Use with West's Sludge Quality Control Procedures."

3. Trainee Handout materials

   Reproduce the following *Trainee Handout* pages and have them available for distribution as called for in the lesson:

   a. None required for Lesson 5.

Instructional Approach: Illustrated lecture with class discussion.

Lesson 6: Respiration Rate Control Procedures

Recommended Time: 60 minutes

Purpose: Respiration rate or specific oxygen uptake rate is a rapid, relatively easy procedure to monitor the biological activity in activated sludge systems. Respiration rate observations correlate well with process conditions, sludge settling qualities and final effluent quality. Respiration rate provides a very useful process evaluation and control tool which can be used in conjunction with F/M, MCRT, and sludge settleability data to identify process problems, to determine problem causes and to guide corrective responses. The troubleshooter must understand and be able to use respiration rate determinations in technical assistance projects.

Training Facilities: As specified in Unit 11, Lesson 1.

Pre-Course Preparation:

1. Trainee texts:

   As specified in Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, pages T11.6.1 - T11.6.6, "Respiration Rate Control Procedures."

3. Trainee Handout materials

   Reproduce the following *Trainee Handout* pages and have them available for distribution as called for in the lesson:

   a. None required for Lesson 6

Instructional Approach: Illustrated lecture with class discussion.

Lesson 7: Identifying Problem Causes in Activated Sludge

Recommended Time: 90 minutes

Purpose: Four major process control decision making tooks, F/M, MCRT, sludge settleability and RR, are used in activated sludge process control, evaluation and troubleshooting. Many operators and troubleshooters routinely use only one or two of these tools and, therefore, attempt to control the process based on limited or partial information. The problem solving exercise in this lesson requires the trainee to solve a generalized process control problem, identify the possible causes of the problem, describe how the actual problem cause would be determined and recommend corrective actions for each possible cause identified. The exercise forces the trainee to look at the interrelationships between the various process control decision making tools.

Training Facilities:

a. Lesson introduction: As specified in Unit 11, Lesson 1.

b. Trainee Problem Solving: One separate breakout room for each trainee work group so that individual work groups have a private quiet area in which to meet and discuss the work group's assigned problem.

c. Trainees Report Findings: As specified in Unit 11, Lesson 1.

Pre-Course Preparation

1. Trainee texts

   As specified in Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, pages T11.7.1 - T11.7.3, "Activated Sludge Process Troubleshooting, Problem Identification and Process Control Response - Problem Statement."

   b. *Trainee Notebook*, page T11.7.4, "Activated Sludge Process Troubleshooting, Problem Identification and Process Control Response - Instructions for Completing Worksheet."

   c. *Trainee Notebook*, pages T11.7.5 - T11.7.12, "Activated Sludge Process Troubleshooting, Problem Identification and Process Control Response - Worksheets."

3. Trainee Handout materials

   Reproduce the following *Trainee Handout* pages and have them available for distribution as called for in the lesson:

   a. *Instructor Notebook*, pages H11.7.1 - H11.7.37, "Activated Sludge Process Troubleshooting, Problem Identification and Process Control Response."

Instructional Approach: Trainee problem solving in work groups of four trainees and discussion of trainee findings.

Lesson 8: Visual Observations in Troubleshooting

Recommended Time: 60 minutes

Purpose: Visual inspection of the activated sludge process offers a quick and simple procedure to gain preliminary information on possible problems in the activated sludge process. It is essential that the troubleshooter know what to look for and how to interpret the results during the visual inspection of the activated sludge treatment system. This lesson presents information about and illustrates the items which should be observed during the visual inspection of the activated sludge process.

Training Facilities: As specified for Unit 11, Lesson 1.

Pre-Course Preparation:

1. Trainee texts

   As specified in Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. None required for Lesson 8.

3. Trainee Handout materials

   Reproduce the following *Trainee Handout* pages and have them available for distribution as called for in the lesson:

   a. None required for Lesson 8.

Instructional Approach: Illustrated lecture with trainee discussion and problem solving.

Lesson 9: Case History: Pullman Treatment Plant

Recommended Time: 50 minutes

Purpose: The purpose of this lesson is to provide trainees an opportunity to apply information presented in Unit 11, Lessons 1 - 8 to problem solving in an activated sludge treatment plant. Trainees apply what they have learned to solution of a case history problem situation.

Training Facilities: As specified in Unit 11, Lesson 7.

Pre-Course Preparation:

1. Trainee texts

   As specified in Lesson 1

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, pages 11.9.1 - 11.9.7, "The Pullman Treatment Plant - Situation and Data."

b. *Trainee Notebook*, page T11.9.8, "Pullman Troubleshooting Problem - Answer Sheet."

3. Trainee Handout materials

Reproduce the following *Trainee Handout* pages and have them available for distribution as called for in the lesson:

a. None required for Lesson 9.

Instructional Approach: Trainee problem solving while working in groups of four trainees.

Lesson 10: Case History: Pullman Treatment Plant - Solution

Recommended Time: 50 minutes

Purpose: Report and discuss trainee responses to the problem presented as Unit 11, Lesson 9. The solution actually implemented at the Pullman Treatment Plant is presented and discussed to illustrate how process mode change can be achieved by modifying the activated sludge return system at a treatment plant and how respiration rate measurements can be used to anticipate influent load changes, monitor process condition and adjust plant operations to achieve consistent effluent quality.

Training Facilities: As specified in Unit 11, Lesson 1.

Pre-Course Preparation:

1. Trainee texts

As specified in Lesson 1.

2. *Trainee Notebook* materials

Reproduce and insert into the *Trainee Notebook* the following:

a. As specified for Unit 11, Lesson 9.

3. Trainee Handout materials

Reproduce the following *Trainee Handout* pages and have them available for distribution as called for in the lesson

a. *Instructor Notebook*, pages H11.10.1 - H11.10.11, "Case History - Pullman Treatment Plant - Solution Implemented."

Instructional Approach: Trainee discussion.

Lesson 11: Hamsborough Case History

Recommended Time: 60 minutes

Purpose: The case history problem solving exercise presented in this lesson permits the trainee to apply the *Process of Troubleshooting* to a small treatment plant which suffers multiple O & M problems in solids handling, activated sludge process operation and the process control laboratory. The problem illustrates the use of relatively inexpensive process modifications which were fabricated by plant personnel to improve the plant's operations.

Training Facilities: As specified in Unit 11, Lesson 7.

Pre-Course Preparation:

1. Trainee texts

   As specified in Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, pages T11.11.1 - T11.11.6, "Activated Sludge Process Troubleshooting, Hamsborough Case History."

3. Trainee Handout materials

   Reproduce the following *Trainee Handout* pages and have them available for distribution as called for in the lesson:

   a. None required in Lesson 11.

Instructional Approach: Trainee problem solving in four person work groups and discussion of trainee findings.

Lesson 12: Sludge Settling Problems

Recommended Time: 120 minutes

Purpose: Many activated sludge process control problems result in an inability to separate and concentrate the mixed liquor suspended solids in the final clarifier. There are numerous causes of settling and concentration problems in the final clarifier. The troubleshooter must be able to identify and distinguish between the different sludge settling problems, identify the probable cause of the problem and recommend appropriate corrective actions. This lesson focuses on the final clarifier portion of the activated sludge system and provides the trainee tools for evaluating final clarifier settling problems and recommending corrective actions.

Training Facilities: As specified in Unit 11, Lesson 1.

Pre-Course Preparation:

1. Trainee texts

   As specified in Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, pages T11.12.1 - T11.12.6, "Final Clarifier Settling Problems."

   b. *Trainee Notebook*, pages T11.12.7 - T11.12.16, "Estimating Final Clarifier Solids Handling Capacity."

3. Trainee Handout materials

   Reproduce the following *Trainee Handout* pages and have them available for distribution as called for in the lesson:

   a. None required for Lesson 12.

Instructional Approach: Illustrated lecture, trainee discussion and trainee problem solving.

Lesson 13: Mini-Case Histories

Recommended Time: 50 minutes

Purpose: This lesson provides the trainee experience in analyzing non-process related problems which occur in activated sludge plants. The lesson presents six short case histories with solutions for various mechanical and hydraulics problems which occur in activated sludge facilities.

Training Facilities: As specified for Unit 11, Lesson 1.

Pre-Course Preparation:

1. Trainee texts

   As specified in Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. None required for Lesson 13.

3. Trainee Handout materials

   Reproduce the following *Trainee Handout* pages and have them available for distribution as called for in the lesson:

   a. None required for Lesson 13.

Instructional Approach: Illustrated lecture with trainee problem solving and discussion.

Lesson 14: Unit Summary

Recommended Time: 50 minutes

Purpose: The Unit of Instruction on activated sludge process troubleshooting includes fourteen lessons. This lesson summarizes the key points in the activated sludge unit of instruction and provides an opportunity for trainees to clarify the information presented in the unit through questions, answers and discussion.

Training Facilities: As specified in Unit 11, Lesson 1.

Pre-Course Preparation:

1. Trainee texts

   As specified in Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, pages T11.14.1 - T11.14.3, "Activated Sludge Process Control Troubleshooting References."

3. Trainee Handout materials

   Reproduce the following *Trainee Handout* pages and have them available for distribution as called for in the lesson:

   a. None required for Lesson 14.

Instructional Approach: Illustrated lecture followed by a question, answer and discussion period.

Presentation Options for the Course Director: It has been the experience of the course developers that the majority of trainees, who have taken this course, are not adequately trained in the operation of activated sludge systems. All trainees, even those who meet all the entry level requirements for the course, benefit from the review provided in lessons 1 - 6 of this unit of instruction. These lessons have a further benefit in "leveling" the class and introducing common nomenclature, terminology and definitions which form the basis for developing activated sludge process control and troubleshooting skills.

Therefore, the course developers recommend that the total instructional hours recommended for this unit of instruction be used. Even though the recommended hours of instruction (13½) are long compared to other units of instruction in the course, the course developers suggest that expansion rather than reduction of the hours devoted to activated sludge process troubleshooting be considered by the Course Director. This, of course, would depend on the entry skills of the trainees admitted to the course.

One expansion of the materials, which the course developers have used with great success in operator training courses based on the activated sludge unit of instruction, is to add a 4-6 hour "in-plant" laboratory session. During the in-plant laboratory session trainees, working in groups of four, collect data, gather samples and perform process control tests required to evaluate the plant. The following day the class and instructor interpret the data gathered in terms of the plant's performance, any problems which were observed during the in-plant session and how any process change might impact the plant's performance. If an in-plant session as described above is included in the course, the Course Director should assemble historical data, including flow schematics and design data, for distribution to the class. The Course Director must also assure that all laboratory equipment and supplies are available for the class to collect samples and perform the respiration rate, sludge settleability, microscopic examination and centrifuge solids tests while at the plant. The Course Director must arrange with the plant superintendent to provide data for tests such as BOD and gravimetric suspended solids which cannot be run in the half day in-plant session. If the plant superintendent is willing, it is possible to organize the in-plant session as a mini-troubleshooting exercise consisting of interview with the plant superintendent, guided visual inspection of the plant, sampling program definition, sampling and testing, evaluation of data, problem identification, definition of alternative solutions and recommendations for corrective actions as appropriate.

The Course Director does have some flexibility in sequencing the fourteen lessons in the Unit of Instruction. Lesson 8 may be scheduled any time after Lessons 1, 2 and 3 have been completed. Lesson 7 must be completed before

Lessons 9, 10 and 11 are presented. Lesson 11 may preceed Lessons 9 and 10. Lesson 9 should be scheduled as the last instructional hour in the training day with Lesson 10 scheduled as the first instructional hour the next day. Lessons 7 and 8 must be completed before Lessons 12 and 13 are presented, but Lessons 12 and 13 may preceed Lessons 9, 10 and 11.

Summary of Unit of Instruction 11: Activated Sludge

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Introduction to Activated Sludge Process Troubleshooting 60 minutes	1. Define activated sludge process objective	1. Objectives of the Unit of Instruction	1. Illustrated lecture with class discussion	1. *Trainee Notebook*, page T11.1.1
	2. Identify controllable variables in activated sludge processes	2. Activated sludge process objective and the concept of sludge quality		2. *Instructor Notebook*, pages 11.1.1 - 11.1.44
	3. Identify factors which affect activated sludge process performance	3. The operator's goals and functions in process control		3. Slides 179.2/11.1.1 - 179.2/11.1.20
		4. Controllable variables which can be manipulated to achieve the activated sludge process objective		4. *Operational Control Procedures for the Activated Sludge Process*
		5. Factors which affect sludge quality and hence impact the achievement of the process objective		5. *Operator's Pocket Guide to Activated Sludge*
				6. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
2. Process Control Concepts for Activated Sludge	1. Define activated sludge process control parameters	1. Activated sludge process parameter formulas, limitations and uses	1. Illustrated lecture with classroom discussion	1. *Trainee Notebook*, pages T11.2.1 - T11.2.8
50 minutes	2. Identify uses and limitations of process control parameters	2. Effect of solids storage in the final clarifier on process control management		2. *Instructor Notebook*, pages 11.2.1 - 11.2.40
	3. Define final clarifier process control strategies	3. Use of trend data in process control		3. Slides 179.2/11.2.1 - 179.2/11.2.15
	4. Identify significance of trend charts in process control			4. *Operational Control Procedures for the Activated Sludge Process*
				5. *Operator's Pocket Guide to Activated Sludge*
				6. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilitis*

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
3. Activated Sludge Process Variations 25 minutes	1. Identify activated sludge process variations	1. Performance characteristics of activated sludge process variations	1. Illustrated lecture with class discussion	1. *Trainee Notebook*, pages T11.3.1
	2. Identify performance characteristics of activated sludge process variations	2. Application of mode change to activated sludge process troubleshooting		2. *Instructor Notebook*, pages 11.3.1 - 11.3.9
	3. Discuss application of mode change to activated sludge process troubleshooting			3. Slides 179.2/11.3.1 - 179.2/11.3.6
				4. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 56-57
4. Microscopic Evaluation of Sludge 25 minutes	1. Relate microscopic observations to sludge quality	1. Activated sludge microorganisms and their relationship to sludge quality	1. Illustrated lecture with class discussion	1. *Trainee Notebook*, pages T11.4.1 - T11.4.2
	2. Describe procedures for microscopic evaluation of activated sludge	2. Procedures for using the microscope to examine activated sludge		2. *Instructor Notebook*, pages 11.4.1 - 11.4.22

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
4. Continued				3. Slides 179.2/11.4.1 - 179.2/11.4.22
				4. *Operator's Pocket Guide to Activated Sludge, Part I: The Basics*, pages 7 - 9
5. Process Control Based on Sludge Settleability 50 minutes	1. Describe laboratory procedures for measuring sludge settleability	1. Laboratory procedures and calculations to measure sludge settleability	1. Illustrated lecture with class discussion	1. *Trainee Notebook*, pages T11.5.1 - T11.5.8
	2. Describe relationship of settling characteristics to sludge quality	2. Procedures to use settling data in process control decision making		2. *Operational Control Procedures for the Activated Sludge Process, Parts I and 2*
	3. Describe how sludge settling characteristics are interpreted for process control	3. Factors which affect sludge settleability		3. *Instructor Notebook*, pages 11.5.1 - 11.5.27
	4. Describe how process operating parameters affect sludge settleability	4. Relationship of sludge settleability to MCRT, F/M and RR		4. Slides 179.2/11.5.1 - 179.2/11.5.29
	5. Relate process control parameter observations to settling characteristics			

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
6. Respiration Rate Control Procedures 60 minutes	1. Define RR	1. Laboratory procedures and calculations to determine respiration rate	1. Illustrated lecture with class discussion	1. *Trainee Notebook*, pages T11.6.1 - T11.6.9
	2. Describe RR test procedures	2. Factors which affect respiration rate		2. *Instructor Notebook*, pages 11.6.1 -11.6.27
	3. Explain the significance of RR measurements in process control	3. Interpretation of respiration rate data for process control		3. Slides 179.2/11.6.1 - 179.2/11.6.49
	4. Relate RR measurements to F/M, MCRT, and sludge settleability observations	4. Relationship of process respiration rates to MCRT, F/M and sludge settleability		
	5. Describe the effect of process control changes on respiration rate observations			
7. Identifying Problem Causes in Activated Sludge 90 minutes	1. Interpret process control parameter observations to identify problems, their causes and corrective actions	1. Alternative causes for observed change in a given process control parameter	1. Trainee problem solving	1. *Trainee Notebook*, pages T11.7.1 - T11.7.11

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
7. Continued	2. Discuss and justify findings	2. Additional data needed to confirm most likely cause of an observed change in a given process control parameter	2. Trainee reports of findings	2. *Instructor Notebook*, pages 11.7.1 - 11.7.9
	3. Define interrelationships between process control parameter observations	3. Corrective actions to respond to possible causes of process control problem in activated sludge	3. Discussion of findings	3. *Instructor Notebook*, pages H11.7.1 - H11.7.27 (Handout to be reproduced prior to the class session)
			4. Distribution of solution sheets	
8. Visual Observations in Troubleshooting 60 minutes	1. Apply the Process of Troubleshooting to activated sludge process	1. The Process of Troubleshooting	1. Illustrated lecture	1. *Operational Control Procedures for the Activated Sludge Process, Part I*
	2. Describe visual observations to be made and their significance in troubleshooting	2. Visual observations in activated sludge plants and their significance in process control and troubleshooting	2. Trainee problem solving and discussion	2. *Instructor Notebook*, pages 11.8.1 - 11.8.25
	3. Demonstrate an ability to interpret visual observations			3. Slides 179.2/11.8.1 - 179.2/11.8.67

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
9. Case History: Pullman Treatment Plant 50 minutes	1. Apply the process of troubleshooting to a case history problem	1. Pullman Treatment Plant background information and problem statement	1. Trainee problem solving	1. *Trainee Notebook*, pages T11.9.1 - T11.9.8
			2. Instructor answers trainee questions by role playing the operator	2. *Instructor Notebook*, pages 11.9.1 - 11.9.6
10. Case History: Pullman Treatment 50 minutes	1. Report findings of lesson 9 problem solving exercise	1. Trainee solutions to the Pullman Case History	1. Trainee's report findings	1. *Trainee Notebook*, pages T11.9.1 - T11.9.8
	2. Present solution actually implemented at Pullman	2. Solution implemented at Pullman	2. Instructor leads discussion	2. *Instructor Notebook*, pages 11.10.1 11.10.6
	3. Demonstrate application of respiration rate control procedures		3. Instructor presents actual solution using illustrated lecture technique	3. Slides 179.2/11.10.1 - 179.2/11.10.8
			4. Instructor distributes solution to Pullman problem	4. *Instructor Notebook*, pages H11.10.1 - H11.10.11 (Handout to be reproduced prior to class session)

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
11. Hamsborough Case History 60 minutes	1. Apply the process of troubleshooting to an activated sludge plant problem	1. Hamsborough Treat Plant problem statement	1. Trainee problem solving	1. *Trainee Notebook*, pages T11.11.1 - T11.11.6
	2. Report findings of of problem solving	2. Trainee findings for Hamsborough problem	2. Trainees report and discuss their findings	2. *Instructor Notebook*, pages 11.11.1 - 11.11.7
		3. Solution implemented at Hamsborough	3. Instructor presents the solution implemented at Hamsborough	3. Slides 179.2/11.11.1 - 179.2/11.11.23
12. Sludge Settling Problems 120 minutes	1. Identify four types of sludge settling problems	1. Bulking definition	1. Illustrated lecture with class discussion	1. *Trainee Notebook*, pages T11.12.1 - T11.12.16
	2. Define bulking	2. Types of sludge settling problems		2. *Instructor Notebook*, pages 11.12.1 - 11.12.47
	3. Identify the causes of sludge settling problems	3. Causes of sludge settling problems		3. Slides 179.2/11.12.1 - 179.2/11.12.54
	4. Recommend corrective actions for different sludge settling problems	4. Corrective actions for sludge settling problems		
	5. Estimate final clarifier solids handling capacity	5. Procedures to estimate final clarifier solids handling capacity		

Summary of Unit of Instruction 11: Activated Sludge (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
13. Mini-Case Histories 50 minutes	1. Apply the process of troubleshooting to the following problems	1. Verbal and visual descriptions of problem statements and solutions	1. Instructor presents problem	1. *Instructor Notebook*, pages 11.13.1 - 11.13.11
	a. Hydraulic surging b. Flow imbalance c. Short circuiting d. Return sludge control at small plants e. Inadequate mixing f. Final clarifier flow imbalance		2. Trainees solve problem 3. Trainees report findings 4. Class discusses problems and findings	2. Slides 179.2/11.13.1 - 179.2/11.13.28
14. Unit Summary 50 minutes	1. Summarize Unit of Instruction	1. Principal points covered in Unit of Instruction 11, Activated Sludge	1. Illustrated lecture	1. *Trainee Notebook*, pages T11.14.1 - T11.14.3
	2. Answer questions from class	2. Respond to questions asked by trainees	2. Question and answer period	2. *Instructor Notebook*, pages 11.14.1 - 11.14.21 3. Slides 179.2/11.14.1 - 179.2/11.14.7

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 1: Introduction to Activated Sludge Process Troubleshooting

Lesson 1 of 14 lessons Recommended Time: 60 minutes

Purpose: Activated sludge wastewater treatment is achieved through a series of complex aerobic biological processes followed by a physical separation (settling) of the activated sludge from the treated wastewater. Many variables, both variables external to and variables internal to the process, affect the overall efficiency of the activated sludge process. The introductory lesson provides a simplified review of activated sludge treatment theory, defines terminology used in the other lessons of the Unit of Instruction, identifies the variables which affect activated sludge process operations and discusses the significance of each variable to activated sludge process operations and troubleshooting.

Trainee Entry Level Behavior: Trainees will have completed Unit 2, *Elements of Troubleshooting*, before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson the trainee will be able to:

1. From memory, name and describe the five major components of the activated sludge process;
2. From memory, state the objective of activated sludge process treatment;
3. From memory, list five variables which the activated sludge plant operator can manipulate to affect activated sludge process control;
4. From memory, describe in qualitative terms the biological reactions which occur in aerobic degradation of organic materials and relate the degradation process to the bacterial growth curve;

5. From memory, list at least eight factors which affect the efficiency of activated sludge systems and explain the significance of each factor in achieving the process objectives;

6. From memory, define sludge quality by comparing good and bad sludge quality in terms of settling velocity, concentration time, floc appearance, supernate appearance, color and odor;

Instructional Approach: Illustrated lecture with class discussion.

Lesson Schedule: The following schedule should be followed in presenting this lesson:

TIME	SUBJECT
0 - 5 minutes	Introduce Activated Sludge Unit of Instruction
5 - 15 minutes	Activated Sludge Process Objective
15 - 25 minutes	Sludge Quality
25 - 30 minutes	Operator's Objectives
30 - 50 minutes	Activated Sludge Process Reactions
50 - 60 minutes	Review and Discussion

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T11.1.1, "Activated Sludge Process Troubleshooting Lesson Objectives."

2. *Trainee Notebook*, pages T11.2.1 - T11.2.5.

3. *Operators Pocket Guide to Activated Sludge*, Parts I and II, STRAAM Engineers, Inc., Portland, Oregon (1975).

4. West, A.W., *Operational Control Procedures for the Activated Sludge Process*, Parts I, II, IIIA, IIIB and Appendix, U. S. Environmental Protection Agency, National Training and Operational Technology Center, Cincinnati, Ohio.

5. West, A. W., "Updated Summary of the Operational Control Procedures for the Activated Sludge Process," U. S. Environmental Protection Agency, National Training and Operational Technology Center, Cincinnati, Ohio.

6. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pp. 55-76, 118-128 and 182-198, EPA-430/9-78-001, Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (January, 1978).

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 11, Lesson 1, pages 11.1.1 - 11.1.44.

2. Slides 179.2/11.1.1 - 179.2/11.1.20.

Instructor Materials Recommended for Development: None

Additional Instructor References:

1. *Process Control Manual for Aerobic Biological Wastewater Treatment Facilities*, EPA 430/9-77-006, U. S. Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (March, 1977).

2. *Operation of Wastewater Treatment Plants, MOP/11*, Chapters 11 and 12, Water Pollution Control Federation, Washington, D.C. (1976).

3. Metcalf & Eddy, Inc., *Wastewater Engineering Treatment Disposal Reuse*, Chapters 9 and 10, McGraw-Hill Book Company, New York, NY (2nd edition, 1979).

4. Eckhoff, D.W. and D. Jenkins, *Activated Sludge Systems: Kinetics of the Steady and Transient States*, Report No. 67-12, SERL, University of California, Berkeley, CA (December, 1967).

5. Stewart, M. J., "Activated Sludge Process Variations. The Complete Spectrum," Article in 3 parts, *Water and Sewage Works*, *111(RN)*, pp. R241-R262, November 30, 1964.

6. *Inspectors Guide for Evaluation of Municipal Wastewater Treatment Plants*, EPA 430/9-79-010, U. S. Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (April, 1979).

7. Pipes, W. O., "Bulking of Activated Sludge," *Advances in Applied Microbiology*, No. 9, 1967.

8. Nemke, J., "Visual Observations Can be Process Control Aids," *Deeds and Data*, September, 1975.

9. Meers, J. E., "Activated Sludge Process Control," *The Digester*, Illinois Environmental Protection Agency, Springfield, IL (May, 1975).

10. Hatfield, W. D., "Operation of the Activated Sludge Process," *Journal Water Pollution Control Federation*, *38*, No. 6 (June, 1966).

11. Sherrard and Kincannon, "Operational Concepts for the Activated Sludge Process," *Water and Sewage Works* (March, 1974).

12. *Package Treatment Plant Operations Manual*, EPA-430/9-77-005, U. S. Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (April, 1977).

13. *Operators Pocket Guide to Activated Sludge*, Parts I and II, STRAAM Engineers, Inc., Portland, Oregon (1975).

14. West, A. W., *Operational Control Procedures for the Activated Sludge Process*, Parts I, II, IIIA, IIIB and Appendix, U. S. Environmental Protection Agency, National Training and Operational Technology Center, Cincinnati, Ohio.

15. West, A.W., "Updated Summary of the Operational Control Procedures for the Activated Sludge Process," U. S. Environmental Protection Agency, National Training and Operational Technology Center, Cincinnati, Ohio.

16. *Wastewater Treatment Plant Operator Training Program Intermediate Course*, Water Pollution Control Federation, Washington, D C.

17. *Manual of Wastewater Operations*, Texas Water Utilities Association, Austin, Texas (1971).

Classroom Set-Up:

1. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees in groups of four;
2. Instructor table with lectern;
3. Large projection screen (6' x 6' minimum) and chalkboard in front of room and readily seen by all trainees;

4. Easel with pad;

5. 35mm carousel projector with remote control changer at instructor table;

6. At least four empty carousel trays;

7. Overhead projector;

8. Chalk, felt-tip markers and erasers;

9. Six to eight chairs randomly spaced at back and sides of room for visitors.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	All slides in this lesson are available as print masters which can be used to make overhead transparencies.
I. Introduce Activated Sludge Unit of Instruction (5 minutes) A. Importance of Activated Sludge Treatment 1. During recent years has become most widely used secondary treatment process 2. Activated sludge plants come in all sizes and shapes from small single unit package plants to plants treating more than 1 billion gallons per day. 3. Activated sludge plants can perform very efficiently if they are properly designed. More importantly, activated sludge plants require intensive process control and operations to maintain process balance and achieve good treatment efficiency. 4. Compared to other processes, activated sludge is complex. Both operators and technical assistance personnel have more "operational" problems with activated sludge than with other processes. 5. There seems to be some "mistique" about activated sludge which causes operators and technical assistance personnel to be "afraid" of activated sludge. 6. Because of its wide and diverse uses and operational problems with	Use Slide 179.2/11.1.1 Slide 179.2/11.1.1 is a blank used to blacken screen.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
activated sludge systems, the course devotes about 12 hours to activated sludge process control and troubleshooting. Unlike other units in the course, the activated sludge unit devotes significant time to the theory and routine process control procedures for activated sludge before developing the troubleshooting information on the systems.	
B. Objectives of the Unit	Refer class to *Trainee Notebook*, page T11.1.1, "Activated Sludge Process Troubleshooting Lesson Objectives"
1. Refer class to *Trainee Notebook*, page T11.1.1, "Activated Sludge Process Troubleshooting Lesson Objectives."	
2. Briefly review lesson objectives with class.	
3. Briefly review Agenda and timing for the Activated Sludge Unit of Instruction.	
4. Introduce other instructors who will participate in the Activated Sludge Unit of Instruction.	
C. *Trainee Notebook* Materials for Activated Sludge	
1. Briefly introduce trainees to the Activated Sludge section of the *Trainee Notebook*.	
2. Point out additional handouts on Activated Sludge that are included in the *Trainee Notebook:*	
a. *Operators Pocket Guide to Activated Sludge*, Parts I and II.	
b. *Operational Control Procedures*	

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

for the Activated Sludge Process, by A. W. West, pamphlet series in five parts.

c. *Field Manual for Process Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*

   1) pp. 55-76, Activated Sludge
   2) pp. 118-128, Settling Tanks
   3) pp. 182-198, Nitrification and Denitrification

D. Answer any questions from the class

II. Activated Sludge Process Objective (10 minutes)

A. Activated Sludge Process Description

1. Activated sludge treatment compresses in time and space aerobic biological reactions which occur naturally in streams.

a. Soluble or non-settleable organic materials discharged to a receiving water naturally decay in the presence of aerobic and facultative microorganisms causing:

   1) Decrease in D.O.
   2) Potential septic conditions
   3) Disposition of settleable solids
   4) Potential for floating solids
   5) Potential for odors
   6) Potential destruction of higher aquatic forms

783

LESSON OUTLINE | KEY POINTS & INSTRUCTOR GUIDE

   7) All the symptoms of water pollution

b. Above processes may take several hours or even days to occur in the receiving water.

c. Activated sludge compresses the above processes in time by:

   1) Concentrating the aerobic and facultative microorganisms
   2) Providing adequate oxygen supply
   3) Concentrating and returning microorganisms to the process
   4) Providing a settling tank

d. Compression of reactions in time permits compression in space because smaller volumes (shorter detention times) are required to complete the biological reactions.

e. In most activated sludge systems

   1) Aerobic biological reactions are completed with 1 to 24 hours wastewater detention time in the system.
   2) Deposition (settling) occurs in 1 to 4 hours because of the quiescent flow conditions created in settling basins

2. Activated Sludge System Components

a. Activated sludge system components and their functions

LESSON OUTLINE

1) Use Slide 179.2/11.1.2 to illustrate the activated sludge system

2) Point out major components and describe their purposes or functions

   a) Aeration Tank

      1 Provides space (volume) for contacting wastewater microorganisms (activated sludge) and oxygen

      2 Provide sufficient detention time to permit microorganisms to assimilate organic materials in wastewater

   b) Air Supply System

      1 Provide oxygen to keep aeration tank aerobic (D.O. greater than 1.0 mg/l)

      2 Provides mixing energy for contacting wastewater and microorganisms.

   c) Mixed Liquor

      1 Mixture of wastewater and microorganisms (activated sludge) is called mixed liquor

      2 Activated sludge solids in mixed liquor are called mixed liquor sus-

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.1.2

Slide 179.2/11.1.2 is a schematic diagram of a conventional activated sludge process showing the major process streams and components with labels.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
pended solids (MLSS)	
3 MLSS are usually measured and reported as	
a MLTSS, mixed liquor total suspended solids (sometimes abbreviated as MLSS)	
b MLVSS, mixed liquor volatile suspended solids	
d) Secondary Clarifier System	
1 Provides quiescent flow conditions, space and time to permit MLSS to separate from the liquid phase to produce a clarified supernate and a concentrated blanket of activated sludge solids	
2 Provides mechanism to remove clarified liquid, now called secondary effluent, as an overflow stream from the clarifier	
3 Provides mechanism to collect and remove the sludge blanket solids as an underflow solids stream	

4 The total underflow from the final clarifier is called the clarifier sludge flow (CFS) and is equal to the sum of the return activated sludge flow and the waste activated sludge flow

5 In addition to the clarification function, the secondary clarifier also serves as a gravity thickener to concentrate the underflow solids.

6 Secondary clarifiers are frequently called final clarifiers

e) Return Activated Sludge System

1 The major portion of the secondary clarifier underflow solids are returned to the head of the aeration tank where the recycled solids are mixed with the untreated wastewater feed to the aeration tank. The portion of solids recycled is called return activated sludge

2 Return activated sludge system normally contains a

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
return sludge pump and should contain a system to vary, control, and measure the return sludge flow rate, abbreviated RSF for Return Sludge Flow	
3 The concentration of activated sludge solids in the return sludge flow is called the Return Sludge Concentration, RSC	
4 The return sludge concentration will vary from only slightly greater than the MLSS concentration to several mass percent activated sludge solids depending on the RSF, the settling characteristics of the activated sludge solids, the hydraulics in the final clarifier and several other factors which are of lesser importance	
5 Depending on the type of activated sludge system, the system design and the systems operation, the return sludge flow will normally be in the range 25-200% of	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
the influent wastewater flow rate	
f) Waste Activated Sludge System	
1 The portion of the clarifier sludge flow removed from the system and sent to sludge processing and disposal is called Waste Activated Sludge (WAS). Sometimes the WAS is called excess activated sludge and WAS flow is sometimes abbreviated XSF.	
2 In some systems the waste activated sludge removal system is independent of the return sludge system with a separate WAS pumping, flow control and metering. However, in most systems sludge is wasted from the return sludge line. A few systems waste mixed liquor directly.	
3 Waste sludge must be separately metered and independently controlled irrespective of the stream used as the source of waste activated sludge.	

LESSON OUTLINE

4 Waste activated sludge concentrations (XSC) and flows (XSF) must be measured and controlled.

5 Some systems use a very informal and uncontrolled system for wasting activated sludge solids. This system is called excess or high effluent suspended solids.

B. Activated Sludge Process Objective

1. Ask trainees to provide a statement of the activated sludge process objective, i.e., what are we trying to accomplish in activated sludge wastewater treatment?
2. Briefly discuss trainee contributions.
3. Guide discussion to following definition:
   a. The objective of activated sludge wastewater treatment is to convert non-settleable biodegradable pollutants to settleable solids to produce a clarified effluent low in TSS or BOD and to provide for the disposal of the settleable solids in a safe and economic manner.
   b. Use Slide 179.2/11.1.3 to illustrate the major points

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.1.3

Slide 179.2/11.1.3 is a word

in the definition of the process objective

c. Briefly discuss following key words in the process objective

1) Convert - by aerobic biological processes change influent pollutants to bio-mass (activated sludge solids). Some portion may go to harmless by-products.

2) Non-settleable - dissolved and colloidal materials in raw wastewater which are not removed by primary treatment

3) Biodegradable - those raw wastewater organics which can be assimilated and stabilized by aerobic microorganisms, i.e., activated sludge solids

4) Settleable solids - solids which can be removed in the secondary clarifier by simple gravity sedimentation

5) Low in TSS and BOD - a properly designed and operated activated sludge system should consistently produce an effluent meeting NPDES conditions. West claims that a conventional

slide which reads:

"Activated Sludge Process
Objective

Convert Non-Settleable Biodegradable Pollutants to Settleable Solids to Produce a Clarified Effluent Low in TSS and BOD" activated sludge process should produce an effluent with less than 10 mg/l TSS or BOD. Normally an effluent with a low TSS will have a low BOD; an effluent with a high TSS will have a high BOD. About 70% of the effluent BOD in activated sludge plants is suspended BOD. Only about 30% is soluble BOD.

d. If the activated sludge process objective is to produce settleable solids, then the process should be viewed as a solids production process as a primary function with treatment of liquid wastes as a beneficial by-product of settleable solids production. Several persons, most notably West, have observed that activated processes which produce good settleable sludges produce clear, low BOD effluents

III. Sludge Quality (10 minutes)

A. Use Slide 179.2/11.1.4 to compare good and bad sludge quality

B. Note that slide notes observations of sludge settling which would be made in a settleometer or other mixed liquor settling test

C. Briefly discuss the observations used to compare good and poor sludge quality Refer to West's pamphlets listed in the references for detailed discussion of each point

Use Slide 179.2/11.1.4
Slide 179.2/11.1.4 is a word slide which reads:

"Settleable Solids Sludge Quality

GOOD

- Settles Fairly Rapidly
- Concentrates Uniformly in 30-60 minutes
- Flocculent
- Clear Supernate
- Deep Tan to Brown

LESSON OUTLINE

D. Note that good sludge quality normally produces a good effluent quality

E. Note that good or acceptable sludge quality will not be the same at all plants. Many factors affect sludge quality. Among these are:

   1. Waste characteristics

   2. Physical configuration of the plant

   3. Operating parameters

      a. Return sludge rate
      b. Solids inventory
      c. Mean Cell Residence Time
      d. Solids distribution in plant
      e. Aeration rates
      f. Detention times

   4. Temperature

F. The troubleshooter or operator must determine the "good" sludge quality for his plant. A good sludge is one that produces the best quality effluent. The troubleshooter or operator must then adjust the process to maintain the sludge quality which gives the best effluent.

G. Careful observation and monitoring of sludge quality will indicate changes which must be made in process control variables to maintain process balance and good effluent quality. Sludge quality is a very sensitive indicator of process conditions and provides early clues to changes in process condition which could adversely affect effluent quality.

KEY POINTS & INSTRUCTOR GUIDE

BAD

- Settles Very Fast or Very Slowly
- Concentrates Very Rapidly (30 minutes) or Very Slowly (2-4 hours)
- Granular or Excessively Fluffy
- Cloudy, Turbid, Straggler Floc, Pin Floc or Ashing
- Light Tan, Very Dark Brown or Black"

LESSON OUTLINE

IV. The Operator's Objective (5 minutes)

A. The Operator's Objective

1. Emphasize key points in definition
   a. Convert non-settleable to settleable
   b. Produce settleable solids which can be removed in the final clarifier
   c. Waste excess solids as necessary to disposal
   d. Maintain conditions which accomplish the above
2. The troubleshooter's objective is to help the operator identify conditions which will achieve the process objective.

B. Operator's Functions

1. Review functions on slide 179.2/11.1.6
2. Emphasize the importance of proper interpretation of observations and laboratory test results to define specific and correct adjustments in the process to maintain process balance, process control, good sludge quality and hence good effluent quality
3. Troubleshooters role is to help the operator develop skills to perform his/her essential process control functions.

C. Controllable Variables

1. Discuss points on Slide 179.2/11.1.7

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.1.5

Slide 179.2/11.1.5 is a word slide which reads:

"Activated Sludge Operator's Objective

Maintain environmental conditions to maximize conversion of non-settleable pollutants to settleable solids and remove the settled solids from the system so that they can be disposed of safely"

Use Slide 179.2/11.1.6

Slide 179.2/11.1.6 is a word slide which reads:

"Activated Sludge Operator's Functions

Exercise proper operational control of the system

1. Observation
2. Laboratory Testing
3. Interpretation of Results
4. Adjust Controllable Parameters"

Use Slide 179.2/11.1.7

Slide 179.2/11.1.7 is a word slide which reads:

LESSON OUTLINE

2. Key points to make:

   a. Direct control of air supply indirectly controls oxygen transfer rate, D.O. in the aeration basin, and mixing in the aeration basin.

   b. Direct control of return sludge flow rate indirectly affects return sludge concentration, MLSS concentration, aeration basin detention time, final clarifier hydraulics and distribution of solids in the system.

   c. Direct control of waste sludge volume indirectly controls total amount of excess sludge wasted, solids inventory in the system, Mean Cell Residence Time (MCRT), Food to Microorganism Ratio (F/M), final clarifier hydraulics, and concentration of final clarifier underflow solids concentration.

   d. In some activated sludge systems, the operator can vary the aeration tank or final clarifier tank volumes in use or can control distribution patterns between tanks to change sludge aeration time, i.e., use one or more tanks for sludge reaeration.

   e. Application of additives such as coagulant aids, settling aids, odor control and chlorination of return to control bulking are control options available to the operator but their use may not be recommended

KEY POINTS & INSTRUCTOR GUIDE

"Operator Controls

1. Air Supply
2. Return Sludge Flow Rate
3. Waste Sludge Volume
4. Aeration Volume
5. Application of Additives
6. Limited Control on Influent Sewage"

LESSON OUTLINE

f. Through the sewer use control ordinance, pretreatment ordinance or influent equalization the operator may have some, although probably limited, control over the waste received by the plant

V. Activated Sludge Process Reactions (30 minutes)

A. Adsorption and Absorption of Food

1. Role of activated sludge microorganisms

a. Activated sludge consists of many different kinds of microorganisms. (The microbiology of activated sludge will be discussed in more detail in Lesson 4 of this Unit of Instruction.) Of the many species of microorganisms in activated sludge, the bacteria are the most important in stabilizing organics in the wastewater.

b. Bacteria need food for two primary purposes:

1) Provide chemical energy for growth and maintenance of life functions

2) Provide the carbon, nitrogen, phosphorous, oxygen, hydrogen, etc. atoms which are assimilated to form new bacterial mass (biomass)

2. Sorption Mechanisms

a. Microorganisms can use only soluble organics which pass through the cell membrane as a source of energy and mass

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.1.8
Slide 179.2/11.1.8 is a schematic diagram illustrating the steps involved in adsorption and absorption of food by an activated sludge bacterium"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. Soluble biodegradable organics in the wastewater are absorbed directly into the bacterium where metabolic reactions yield energy, form new biomass and produce metabolic by-products such as carbon dioxide and water which are released from the bacterium back into the liquid phase.	
c. Suspended particles are adsorbed onto the surface of the bacterium cell but cannot enter the cell until they are dissolved.	
1) The bacterium excretes enzymes (extracellular enzymes) which solubilize the adsorbed organics.	Define enzyme as a complex organic molecule produced by living forms. The enzyme acts as a catalyst to accelerate the rates of biochemical reactions.
2) These enzymes also affect free organic particles and accomplish some solubilization of particles which have not been adsorbed in the liquid phase.	
3) The soluble organics produced by the action of extracellular enzymes on suspended particles are absorbed into the cell and metabolized by the bacterium.	
3. Relative Rates of Adsorption and Absorption Reactions	
a. The adsorption of suspended particles by the bacteria (activated sludge floc) is very fast and normally is completed about 30 minutes after the activated sludge is contacted with the wastewater.	Use Slide 179.2/11.1.9 Slide 179.2/11.1.9 is a graphical presentation of BOD_5 remaining as a function of aeration period.

LESSON OUTLINE

b. The solubilization of adsorbed organics is much slower and requires 4-12 hours for completion.

c. The biological reactions associated with metabolism "stabilize" the waste by conversion of biodegradable organics to new bacterial cell mass and harmless waste products (CO_2 and H_2O), are relatively slower and require about 4-12 hours for completion at normal temperatures (about 68°F or 20°C)

d. The sorption reactions require intimate and complete mixing of the activated sludge and the wastewater. The mass transfer rates are a function of the turbulence in the system.

B. Relationship of Food Availability to Bacterial Growth Rate.

1. Explain that microorganisms reproduce by binary fission

2. Logarithmic growth

   a. With unlimited food and nutrient supply the microorganisms reproduce at maximum rate

   b. Both numbers and mass of the microorganisms increase logarithmically

   c. This is called the logarithmic growth phase

   d. During the log growth phase

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.1.9 to illustrate the relative rates of adsorption, absorption and "stabilization" reactions.

Use Slide 179.2/11.1.10

Slide 179.2/11.1.10 is a graphic representation of the batch culture growth curve of microorganisms. Microorganisms mass is plotted as a function of time. Log growth, declining growth and endogenous growth phases are shown

LESSON OUTLINE

the population doubles with each generation. The time required for the number or mass of microorganisms to double is called the generation time or the maximum growth rate. The rate of growth of the total population is proportional to the number or mass of microorganisms in the population. The maximum growth rate constant is a function of:

1) Species of microorganism

2) Temperature

   a) Increase by 10°C and growth rate constant doubles

   b) Decrease 10°C and growth rate constant decreases by half

3) Nature of food source and nutrient source

   a) Simple carbohydrates are assimilated very rapidly

   b) Proteins are metabolized less rapidly than carbohydrates

   c) Complex organics may be metabolized very slowly

   d) Organisms must be acclimated to the food and nutrient source

KEY POINTS & INSTRUCTOR GUIDE

Note that logarithmic growth is someti[illegible] called exponential growth.

Optional point: Mathematically logarithmic growth can be expressed as:

$$\frac{dx}{dt} = \hat{\mu}X \quad (1)$$

where: X = number or mass of microorganisms with appropriate units

$\hat{\mu}$ = maximum growth rate constant, time^{-1}

t = time, appropriate units

This equation solves to:

$$X(t) = X_o e^{\hat{\mu} t} \quad (2)$$

where: $X(t)$ = number or mass of microorganisms at time t

X_o = number or mass of microorganisms at time $t = 0$

t = time, appropriate units

$\hat{\mu}$ = maximum growth rate, constant, time^{-1}

e = Naperian base

Define acclimate as an adjustment period during which the organism develop a capability to metabolize

LESSON OUTLINE

4) pH

   a) Activated sludge organisms perfer a pH near neutral, pH = 7.0

   b) Activated sludge organisms normally can adapt to pH in the range 6-9

   c) pH less than 6 (acidic) or greater than 9 (basic) inhibits or kills most activated sludge organisms.

5) Presence of Toxic or Inhibitory Substances

   a) Some substances such as heavy metals block metabolic pathways at low concentrations. At higher concentrations they can be toxic and actually kill the organisms.

   b) Many organic substances are inhibitory or toxic, e.g., phenols, chlorinated hydrocarbons, etc.

   c) The effects of some inhibitory compounds is reversible

KEY POINTS & INSTRUCTOR GUIDE

the food source or to adjust to changes in other environmental factors. Bacteria are very flexible and have tremendous capability to adapt to a variety of food sources and environmental conditions because they have the capability to modify metabolic pathways to accommodate to different conditions.

LESSON OUTLINE

3. Declining Growth Phase

   a. Growth consumes food and nutrients. When food and nutrients are present in excess, growth is logarithmic

   b. When food or nutrients become limiting, the growth rate decreases because there is not sufficient food or nutrient to satisfy the growth and maintenance needs of the population

   c. An analogy to overpopulation and the beginning of famine can be used.

KEY POINTS & INSTRUCTOR GUIDE

Optional Points: The rate of food or nutrient consumption is proportional to the rate of growth of the population. The proportionality constant Y_g is called the growth yield coefficient.

$$\Delta X = -Y_g \Delta S$$

where ΔX = increase in bio-mass, mg/l

ΔS = decrease in substrate, mg/l

Y_g = growth yield coefficient, mg biomass produced/ mg substance consumed

In differential equation form this becomes

$$\frac{dx}{dt} = \mu X \qquad \frac{ds}{dt} = \frac{-\mu X}{Y_g} \qquad (3)$$

where s = substrate concentration, mg/l

other terms as defined perviously

The growth rate is a function of the amount of limiting nutrient (food, oxygen, nitrogen, phosphorous, etc.) available to the population. A common mathematical expression for growth rate as a function of limiting nutrient is that proposed by Monod:

LESSON OUTLINE

4. Endogenous Phase

   a. Microorganisms need energy to maintain life functions and cell integrity. This enery can come from two sources:

      1) External food source

      2) Intra-cellular materials

         a) Internally stored food materials

         b) Cell bio-mass (cell protoplasm)

KEY POINTS & INSTRUCTOR GUIDE

$$\mu = \frac{\hat{\mu} S}{(S+K_s)} \qquad (4)$$

where: μ = growth rate constant, time^{-1}

$\hat{\mu}$ = maximum growth rate constant, time^{-1}

S = concentration of limiting nutrient, mg/l

K_S = saturation constant, mg/l

For $S \gg K_S$, $\mu = \hat{\mu}$

All other S, $\mu < \hat{\mu}$

The expression for μ can be substituted into equation (3) to give a generalized equation for growth rate and substrate removal rate. However, the non-linear equation set cannot be solved analytically.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

b. The maintenance energy requirement is continuous and occurs concurrently with growth if sufficient external food is available. If an external food source is not available, the cell begins to consume itself in order to maintain life functions.

c. When the external food supply equals the maintenance energy needed, the population ceases to grow and maintains itself at a constant number or mass. This is called the zero or no-growth phase.

d. If the maintenance requirement exceeds the available external food source, the microorganism will begin to break down nonessential intracellular components in an effort to maintain essential life functions. This is called endogenous metabolism. Since little or no external food is available to support growth, the population begins to decrease resulting in a net negative growth or decline in the population.

e. As endogenous respiration continues, some cells die and lyse (break apart) and release their intracellular materials to the liquid phase. Other cells can then use these released materials as a food source for maintenance and growth.

f. The endogenous phase is very

dynamic because some cells are dying while others continue to reproduce using lysis products and the very limited supply of external food for maintenance and reproduction. Although the total population is decreasing, some individual cells continue to grow and reproduce

g. In activated sludge systems it has been observed that endogenous respiration reduces the bio-mass of the activated sludge by about 5% per day.

h. The decay coefficient, like the maximum growth rate coefficient, increases with increasing temperature and depends on the kinds of microorganisms present. Decay rate is also affected by the presence of toxic and inhibitor substances and by the pH of the culture medium.

i. Point out on the growth curve that there will never be a complete decay of the bio-mass because some cell components, such as cell walls, cannot be metabolized by the biological culture.

j. Because endogenous respiration proceeds concurrently with growth when an external food source is available, the growth observed is the net growth in the system. In activated sludge waste treatment net growth yields are:

Optional Point: The total rate of decay as a result of endogenous respiration can be written as:

$$\left.\frac{dX}{dt}\right|_e = k_d X \qquad (5)$$

where k_d = decay coefficient, 0.05 day^{-1}

$\left.\frac{dX}{dt}\right|_e$ = decay rate as result of endogenous respiration, mass per day

The net growth in the culture can then be written as:

$$\frac{dX}{dt} = (\mu - k_d)X \qquad (6)$$

Since $\mu = \frac{\hat{\mu}S}{K_s + S}$

There will be a net decrease in bio-mass when $S \ll K_s$

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

1) $0.5 - 0.6 \ \frac{\#\text{VSS produced}}{\#\text{ BOD removed}}$

2) $0.3 - 0.4 \ \frac{\#\text{ VSS produced}}{\#\text{ COD removed}}$

5. Relationship of Food Availability to Growth Rate

   a. Point out that when available food and nutrients are large compared to the bacterial population, the growth rate is very rapid. Such conditions are normally associated with logarithmic growth. The bacterial culture will be very active and will consume food, nutrients and oxygen at a rapid rate to support rapid growth in the population. Such conditions produce an "unstable" sludge which exhibits a high oxygen demand. In most activated sludge sys-systems these are conditions which are encountered during start-up or recovery from severe upsets which has destroyed or depleted the activated sludge solids in the system.

Use Slide 179.2/11.1.11
Slide 179.2/11.1.11 is a graphical presentation of the bacterial growth curve (Slide 179.2/11.1.10) with a superimposed curve showing food remaining.

NOTE: Stable is used in the sense of a stabilized waste which shows a limited tendency to undergo further aerobic biological degradation. Stable in this sense means that there is a limited or low rate of biological activity. In aerobic systems it corresponds to conditions when specific oxygen utilization rates are low. Unstable conditions imply high biological activity which corresponds to high specific oxygen utilization rates.

   b. Point out that as the food and nutrients are consumed, the relative amount of food or nutrient per unit mass of biological solids decreases. Consequently, the growth rate

LESSON OUTLINE

decreases and the biological solids are relatively more stable than during the logarithmic growth phase. These conditions correspond to the declining growth phase where there is still a net positive yield of bio-mass.

Note that at some point food supply just balances the maintenance endogenous requirements and there would be an apparent zero growth (no net yield of bio-mass) condition. True zero growth can occur only in batch culture systems. There is no zero growth point in continuous culture systems in which the food and nutrient supplies are continuously replenished. Continuous culture systems, such as activated sludge, will always produce excess sludge solids which must be physically removed from the system.

c. Point out the endogenous phase in which the food and nutrient supply are very low relative to the bio-mass present. Under these batch culture conditions, there is a decrease in the biomass. Even if the growth curve is extended out to very long times, the culture will never reduce to zero mass because non-biodegradable cellular materials which form during growth cannot be digested (broken down and metabolized).

KEY POINTS & INSTRUCTOR GUIDE

Essential Note to Instructor: The growth curve presented is a batch culture growth curve in which the food or nutrient supply is not replenished.

In continuous growth cultures, such as an activated sludge system, food and nutrients are being supplied on a continuous basis. In continuous culture systems there will always be an accumulation (increase) in bio-mass (sludge solids) because the non-biodegradable cell materials will not decay and thus an "inert" fraction of sludge solids will accumulate. Therefore, all aerobic biological systems will produce excess sludge solids which must be physically removed from the system.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
Cultures in the endogenous phase are classified as very stable because they exhibit very low biological acitivty. Such cultures will show a very low specific oxygen utilization rate.	
d. Define F/M	
1) The curves on Slide 179.2/11.1.11 indicate that there is a relationship between biological activity (growth rate, substrate consumption rate, nutrient consumption rate and oxygen utilization rate) and the amount of food or nutrient available per unit of bio-mass (sludge solids) in the culture.	Note: The fundamental realtionship between biological activity (growth rate) and the food to microorganism ratio can be mathematically derived from equations 1 - 6 by writing mass balance equations around continuous culture systems.
2) This observation leads to definition of the Food to Microorganism ratio which is used as a design, process control and troubleshooting parameter in activated sludge systems.	Refer to *Process Control Manual for Aerobic Biological Wastewater Treatment Facilities* (reference 1, page 11.1.3), pages II-15-19 and Metcalf and Eddy, Inc. (reference 3, page 11.1.3) for these derivations.
3) In activated sludge systems the F/M ratio is defined in terms of the mass of biodegradable materials fed to the aeration basin per day and the mass of sludge solids in the aeration system.	Write equation on chalkboard
a) There are several definitions of F/M. Most differ in the definition of solids inventory	

LESSON OUTLINE

1 Some consider only the solids in the aeration basin when calculating F/M

2 Others define the solids inventory as all solids in the aeration-final clarifier system.

b) In this course F/M is defined as:

$$F/M = \frac{\text{\# BOD}_5\text{ Applied/Day}}{\text{Total \# Solids Inventory}}$$

where Total # Solids Inventory equals the solids in the aeration basins plus solids in reaeration basins plus solids in the final clarifier.

c) The definition of F/M as used in this course does not consider how the solids are distributed in the system. The total quantity of solids in the system (aeration plus reaeration plus final clarifiers) is the basis for defining F/M

d) Best results with F/M are obtained when solids inventory is measured as volatile suspended solids although other measures

KEY POINTS & INSTRUCTOR GUIDE

Note: Some authors define F/M in terms of #BOD_5 removed per day rather than in terms of #BOD_5 applied per day.

of solids (total, centrifuge, etc.) could be used.

e) Applied load is measured as BOD_5. COD, TOC, TOD, etc., can be used as a measure of applied load.

6. Relationship Between Growth Curve and Activated Sludge Treatment Systems

   a. Sludge quality defined in terms of sludge settling characteristics and sludge stability (biological activity) can be related to the growth curve. The different activated sludge process modifications are tailored to the sludge quality characteristics associated with each growth phase.

   b. Dispersed growth systems

      1) Operated with very high F/M, logarithmic growth conditions and an unstable sludge which has high biological activity

      2) Advantages are to treat high strength wastes in small volume aeration basins

      3) Sludge produced is dispersed, does not flocculate well, settles very poorly or not at all, and sludge is biologically very active showing high specific oxygen uptake rate

Use Slide 179.2/11.1.12

Slide 179.2/11.1.12 is the same as Slide 179.2/11.1.11 with the following activated sludge process modifications:

Modification	Growth Phase
Dispersed Growth	Log Phase
High Rate	Early Declining Growth
Conventional	Spans Zero Growth Point
Contact Stabilization	
Extended Aeration	Endogenous Phase

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

4) Because solids cannot be easily separated and recycled, process application normally restricted to systems in which a second aeration stage is used or as a pre-treatment for high strength wastes prior to discharge to more conventional treatment trains

5) Other activated sludge systems may experience periods of dispersed growth during start-up or during recovery from severe process upsets

6) Corresponds to F/M > 2

7) Achieves about 50% BOD_5 and TSS removal

8) Very high sludge yields, greater than 0.6 #VSS/ #BOD_5 removed

c. High Rate Systems

1) Usually short detention time complete mixing activated sludge most frequently used to pre-treat high strength wastes

2) Sludge produced is unstable, retains high biological activity, flocculent but slow settling

3) Corresponds to F/M in range 0.7 - 1.2

4) Achieve 60-70% BOD_5 and TSS removal

LESSON OUTLINE | KEY POINTS & INSTRUCTOR GUIDE

5) High sludge yields, greater than 0.6 #VSS/#BOD_5 removed.

6) May encounter these conditions in other activated sludge systems during start-up or during bulking episodes caused by excessive solids wasting.

d. Conventional and Contact Stabilization Systems

1) Normally operate in late declining growth and early endogenous growth phases.

2) Produce relatively stable sludges which flocculate and settle well. Still biologically active byt relatively stable.

3) Normally have F/M in range 0.2 - 0.5.

4) Sludge yields in range 0.5 - 0.6 #Vss/#BOD_5 removed.

5) Conventional activated sludge systems can achieve 95% and greater removal of BOD_5 and TSS. Produce very high quality effluents.

Contact stabilization is less efficient achieving only 75-80% BOD removal.

e. Extended Aeration

1) Operates well into the endogenous growth phase.

2) Produces very stable sludge with low biological activity, normally fast settling sludges with moderate to good flocculation characteristics, may yield turbid

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
effluents because of ashing and carry-over of cell debris	
3) Very high BOD_5 removal (greater than 95%) but lesser efficiency for TSS removal because of ashing problem	
4) Normally operate with F/M less than 0.1	
5) Sludge yields in range 0.1-0.2 #VSS/#BOD_5 removed	
6) Very long aeration detentimes (24 hours)	
7) Extreme case of operation in endogenous zone is aerobic digestion	
7. Generalized Aerobic Biological Reaction	
a. Emphasize that four essential components for activated sludge reactions: 1) Food (BOD_5) 2) Oxygen (D.O.) 3) Nutrients (N, P, Fe, etc.) 4) Microorganisms (activated sludge)	Use Slide 179.2/11.1.13 Slide 179.2/11.1.13 is a verbal statement of the generalized aerobic biological degradation reactions.
b. Emphasize that reactions yield more biological solids as a product. The excess solids must be removed from the system by physical means.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
c. Discuss nutrient requirements 1) Give minimum requirements 2) Nutrient deficiencies can cause a) Dispersed growth b) No growth c) Poor BOD_5 removal d) Poor solids settleability e) Bulking f) Predominance of undesirable organisms	Use Slide 179.2/11.1.14 Slide 179.2/11.1.14 is a word slide which reads: "Nutrient Requirements BOD: N = 20:1 BOD: P = 100:1 BOD: Fe = 200:1"
8. Nitrification/Denitrification a. Review nitrification reaction 1) Aerobic conversion of NH_3-N to NO_3^-N 2) Two stage conversion by two very slow growing bacterial species 3) Reaction consumes alkalinity which can cause pH problems 4) Reaction very temperature dependent 5) Note that all activated sludge systems nitrify to some extent. More and more plants required to completely nitrify before discharging	Use Slide 179.2/11.1.15 Slide 179.2/11.1.15 is a verbal statement of the two stage nitrification reaction
b. Review Conditions for Nitrification	Use Slide 179.2/11.1.16 Slide 179.2/11.1.16 is a word slide which reads:

LESSON OUTLINE

1) Very large quantity of oxygen required - 4.6 #/#NH_3-N

   a) May not have adequate aeration capacity to nitrify

   b) Costly to nitrify unless required to do so

2) Reaction consumes alkalinity - 7.1 # Alkalinity/#NH_3-N

   a) pH reduction during reaction

   b) May need to add alkalinity in the form of lime or soda ash to nitrify and maintain pH

3) Nitrifying organisms are very pH sensitive. Optimum growth in narrow range 7.8-8.9

4) Nitrifiers grow very slowly and are very temperature sensitive. Therefore, must operate at long MCRT.

5) Need carbonaceous BOD

   a) Nitrifiers need carbon for growth

   b) Nitrifiers tend to be non-flocculent. Need some sludge growth on carbonaceous BOD to aid in flocculation and settling. Need 3-4 mg/l carbonaceous BOD per mg/l NH_3-N converted

KEY POINTS & INSTRUCTOR GUIDE

"Conditions for Nitrification

4.6 # Oxygen Per Ammonia
   Nitrogen Converted
7.1 # Alkalinity per # Ammonia
   Nitrogen Converted
pH in Range 7.8-8.9
Long MCRT
Some Carbonaceous BOD"

Refer class to *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 182-198 for detailed discussion of nitrification and denitrification

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
c. Review Denitrification Reaction 1) Denitrifying bacteria reduce NO_3^--N to N_2 2) Reactions occur under anoxic (low D.O.) conditions 3) Significant because denitrification in anoxic final clarifier can cause floating sludge (clumping) causing violation of TSS permit conditions.	Use Slide 179.2/11.1.17 Slide 179.2/11.1.17 is a word slide which reads: "Denitrification Nitrate Nitrogen Reduces to Free Nitrogen Gas Under Anoxic Conditions"
9. Summarize Sludge Yield Relationships a. Use Slide 179.2/11.1.18 to review and quantify sludge yield concepts which were discussed in Section V.B. b. Note that sludge yield decreases with increased MCRT and decreased F/M because of decay. Increasing temperature will also cause a decrease in sludge yield. c. Type of waste affects sludge yield. Some food sources produce more organic solids than do others.	Use Slide 179.2/11.1.18 Slide 179.2/11.1.18 is a word slide which reads: "Sludge Yield 1 #BOD Removed = 0.4-0.6 #VSS 1 #COD Removed = 0.3-0.4 #VSS Yield Coefficient = Y $= \frac{\text{\#VSS Produced}}{\text{\#BOD Removed}}$ MLVSS = 0.7 x MLSS Sludge Decay MLVSS aerated without food will decay (reduce) by about 5% per day. Decay Coefficient = K_d = 0.05/Day"
d. Use Slide 179.2/11.1.19 to review concept of net yield and to indicate how excess sludge production can be estimated	Use Slide 179.2/11.1.19 Slide 179.2/11.1.19 is a word slide which reads:

LESSON OUTLINE

VI. Lesson Summary (5 minutes)

A. Note that many complex and important points have been covered in a short time. Slide 179.2/11.1.20 summarizes the most important concepts which will be used in troubleshooting activated sludge plants

B. Reiterate that the activated sludge process objective is to convert non-settleable biodegradable pollutants to settleable solids

1. Process is aerobic - D.O. must be present

2. Settleable solids means that the biological solids produced can be removed and concentrated in a gravity settling tank called the final clarifier. This means we must maintain a good sludge quality i.e., a sludge which

   a. Settles fairly rapidly

   b. Concentrates well while in the clarifier

   c. Is flocculent - sludges which do not form into large, relatively strong floc particles will not settle

KEY POINTS & INSTRUCTOR GUIDE

"Estimating Sludge Production
Net Yield

# VSS Produced =

Y x #BOD removed - K_D x
# VSS under aeration

Net Yield Coefficient = Y_{net}"

Use Slide 179.2/11.1.20
Slide 179.2/11.1.20 is a word slide which reads:

"Key Points

1. Aerobic Biological Reactions
2. Produce Settleable Solids
3. Reaction Rates are Functions of:
   a. Temperature
   b. Concentration of MLSS or MLVSS
   c. Concentration of Food (BOD)
   d. Types of Organisms in Sludge
   e. Kinds of Food
   f. Available Nutrients (N, P, Fe)
   g. Mixing
   h. Toxic or Inhibitory substances"

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

d. Produces a large volume of clear supernate quickly as it settles

e. Doesn't leave straggler particles, pin floc or ash as it settles

f. Doesn't wash out of the final clarifier as a result of slow settling, clumping (denitrification) or floating sludge (anaerobic decomposition)

g. Doesn't produce bad odors (spetic sludge)

3. If the operator develops and maintains a good sludge quality, the activated sludge system will probably produce a good quality effluent low in both BOD_5 and TSS

4. Good sludge quality is obtained under process conditions which produce a moderately stable sludge, i.e., a sludge which has some biological activity as measured by specific oxygen utilization rate as contrasted to systems which produce understabilized sludges (high biological activity) or overstabilized sludges (very low biological activity)

C. The operators' functions are to observe the process, perform laboratory tests and interpret observations and test results to properly adjust the controllable variables to maintain process balance. The main controls, which the operator has, are aeration rate, return sludge rate, waste sludge rate and varying aeration volume or contacting patterns in the aeration basin.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

D. The troubleshooter's role is to help the operator define the optimum conditions for his process and develop skills and procedures to maintain the process in balance

E. Activated sludge process control and troubleshooting focus on identifying environmental conditions (process state) which will balance and optimize complex biological reactions and control rates to produce a good settling sludge, good sludge quality, and hence, a good quality effluent. Many variables affect the biological system. Most inportant among these are:

1. Temperature - biological reaction rates increase with increasing temperature. A 10°C increase doubles biological reaction rates in the range 0° - 40°C

2. Reaction rates are proportional to the quantity of reactants in the system. The three principal reactants in activated sludge are:

    a. Activated sludge solids, the MLSS or MLVSS

        1) Concentration
        2) Total quantity
        3) Kinds of microorganisms

    b. The food applied - the influent BOD_5

        1) The total quantity applied
        2) The concentration
        3) The kind of food

    c. The nutrients

LESSON OUTLINE

KEY POINTS &
INSTRUCTOR GUIDE

    1) D.O.
    2) Nitrogen
    3) Phosphorous
    4) Iron

3. Mixing is essential to assure that the sludge solids come into intimate contact with the waste

4. Many substances inhibit or kill the sludge solids and greatly reduce reaction rates

F. The next lesson will look in more detail at the factors which affect activated sludge process performance and will develop information on control strategies and parameters which can be used to monitor, evaluate, control and troubleshoot activated sludge systems

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 1: Introduction to Activated Sludge Process Troubleshooting

Trainee Notebook Contents

Lesson Objectives T11.1.1

820

ACTIVATED SLUDGE PROCESS TROUBLESHOOTING

LESSON OBJECTIVES

At the conclusion of the lesson on activated sludge process troubleshooting, you will be able to:

1. State the process objective for the activated sludge system.

2. Describe in qualitative terms the aerobic biological degradation of organic materials, relate the degradation process to the bacterial growth curve, list the principle factors which affect the efficiency of the aerobic biological systems and explain their significance in achieving the process objective.

3. List the variables in the activated sludge process which can be manipulated by the operator to maintain an optimum environment to achieve the activated sludge process objective and explain how a change in each manipulated variable affects the process.

4. List and define the parameters which are used to evaluate and control the activated sludge process, list the samples and laboratory tests needed to determine each parameter, list the advantages and disadvantages of each parameter and explain why no single parameter can be used alone to affect consistent process control.

5. Explain the significance of trend changes in each process control parameter, describe how the process control parameters relate to each other and explain how trend changes in the process control parameters can be interpreted to determine quantitative operator responses in the controllable variables: aeration rate, return sludge flow rate and waste sludge rate.

6. List the most frequently occurring problems in the activated sludge process, list the possible causes for each problem, explain how the process control parameters are used to identify the problem cause and describe the operator responses to correct or prevent each cause.

7. Apply the process of troubleshooting to case history problems in activated sludge process control and recommend corrective actions for each case history.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 2: Process Control Concepts for Activated Sludge

Lesson 2 of 14 lessons — Recommended time: 50 minutes

Purpose: Activated sludge is a complex aerobic biological wastewater treatment process which is affected by many variables, both variables internal and external to the process. Consequently activated sludge systems require diligent and consistent attention to process control to maintain process balance and effluent quality. Numerous techniques and strategies for managing activated sludge systems to affect process control have been proposed and used. This lesson reviews the more commonly used process control concepts and discusses their application to activated sludge performance evaluation and troubleshooting. It is essential that the troubleshooter understand and correctly use the various process control tools if he or she is to be effective in providing technical assistance at activated sludge facilities.

Trainee Entry Level Behavior: The trainee will have achieved the trainee learning objectives of Unit 11, Lesson 1 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson the trainee will be able to:

1. From memory, list and define five parameters which are used as control variables to evaluate and troubleshoot the activated sludge process, list the samples and laboratory tests needed to determine each parameter, compare and contrast each parameter as to advantages and disadvantages in process control and troubleshooting and explain how each is used in process control and why process control and troubleshooting decisions should be based on evaluation of several parameters rather than a single parameter.

2. From memory, describe two strategies for final clarifier operation by listing the advantages and disadvantages of each strategy and explaining why it is important to adopt a consistent strategy for final clarifier operation.

3. From memory, explain the importance of trend charts in activated sludge process control decision making, calculate five or seven day moving averages and describe how to prepare trend charts of activated sludge process control parameters.

4. Given appropriate design, loading and operational data for an activated sludge process, correctly calculate the F/M, MCRT and Gould Sludge Age for the process and prepare appropriate trend charts for the data provided.

Instructional Approach: Illustrated lecture and class discussion

Lesson Schedule: The 50 minutes allocated to this lesson should be scheduled as follows:

TIME	ACTIVITY
0 - 5 minutes	Introduction
5 - 15 minutes	Final Clarifier Operational Strategies
15 - 40 minutes	Process Control Parameters
40 - 45 minutes	Trend Charts
45 - 50 minutes	Summary and Discussion

Trainee Materials Used in the Lesson:

1. *Trainee Notebook*, pages T11.2.1 - T11.2.7, "Activated Sludge Process Control Parameters," and "Calculation of Control Parameters."

2. *Operators Pocket Guide to Activated Sludge*, Parts I and II, STRAAM Engineers, Inc., Portland, Oregon (1975).

3. West, A. W., *Operational Control Procedures for the Activated Sludge Process*, Parts I, II, IIIA, IIIB and Appendix, U. S. Environmental Protection Agency, National Training and Operational Technology Center, Cincinnati, Ohio.

4. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pp. 55-76, 118-128 and 182-198, EPA-430/9-79-001, Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (January, 1978).

Instructor Materials Used in the Lesson:

1. *Instructor Notebook*, Unit 11, Lesson 2, pages 11.2.1 - 11.2.40.

2. Slides 179.2/11.2.1 - 179.2/11.2.15.

Instructor Materials Recommended for Development: The instructor may wish to develop a series of written problems on calculation of process control parameters and preparation of trend charts which would provide trainees practice in performing necessary calculations. Trainees who meet the entry level requirements for *Troubleshooting O & M Problems in Wastewater Treatment Facilities* should already possess these computational skills. Practice problems would be appropriate for trainees who do not possess computational skills.

Additional Instructor References:

1. *Process Control Manual for Aerobic Biological Wastewater Treatment Facilities*, EPA-430/9-77-006, U. S. Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (March, 1977).
2. *Operation of Wastewater Treatment Plants, MOP/11*, Chapters 11 and 12, Water Pollution Control Federation, Washington, D.C. (1976).
3. Metcalf & Eddy, Inc., *Wastewater Engineering Treatment Disposal Reuse*, Chapters 9 and 10, McGraw-Hill Book Company, New York, NY (2nd edition, 1979).
4. Eckhoff, D.W. and D. Jenkins, *Activated Sludge Systems: Kinetics of the Steady and Transient States*, Report No. 67-12, SERL, University of California, Berkeley, CA (December, 1967).
5. Stewart, M. J., "Activated Sludge Process Variations. The Complete Spectrum," Article in 3 parts, *Water and Sewage Works 111*(RN), pp. R241-R262, November 30, 1964.
6. *Inspectors Guide for Evaluation of Municipal Wastewater Treatment Plants*, EPA 430/9-79-010, U.S. Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (April, 1979).
7. Pipes, W. O., "Bulking of Activated Sludge," *Advances in Applied Microbiology*, No. 9, 1967.
8. Nemke, J., "Visual Observations Can be Process Control Aids," *Deeds and Data*, September, 1975.
9. Meers, J. E., "Activated Sludge Process Control," *The Digester* Illinois Environmental Protection Agency, Springfield, IL (May, 1975).
10. Hatfield, W. D., "Operation of the Activated Sludge Process," *Journal Water Pollution Control Federation, 38*, No. 6 (June, 1966).

11. Sherrard and Kincannon, "Operational Concepts for the Activated Sludge Process," *Water and Sewage Works* (March, 1974).

12. *Package Treatment Plant Operations Manual*, EPA-430/9-77-005, U. S. Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (April, 1977).

13. *Operators Pocket Guide to Activated Sludge*, Parts I and II, STRAAM Engineers, Inc., Portland, Oregon (1975).

14. West, A. W., *Operational Control Procedures for the Activated Sludge Process*, Parts I, II, IIIA, IIIB and Appendix, U. S. Environmental Protection Agency, National Training and Operational Technology Center, Cincinnati, Ohio.

15. West, A.W., "Updated Summary of the Operational Control Procedures for the Activated Sludge Process," U. S. Environmental Protection Agency, National Training and Operational Technology Center, Cincinnati, Ohio.

16. *Wastewater Treatment Plant Operator Training Program Intermediate Course*, Water Pollution Control Federation, Washington, D.C.

17. *Manual of Wastewater Operations*, Texas Water Utilities Association, Austin, Texas (1971).

Classroom Set-Up: As specified in Unit 11, Lesson 1, page 11.1.4.

LESSON OUTLINE

I. Introduction (5 minutes)

  A. Factors Affecting Activated Sludge Processes

    1. Activated Sludge Solids (MLSS)

      a. Concentration

      b. Total quantity

      c. Types of organisms

    2. Food

      a. Concentration

      b. Total quantity fed

      c. Type of food

    3. Temperature

    4. Time available for reactions

      a. Aeration detention time

        1) Hydraulic detention time

        2) Solids detention time

      b. Clarifier detention time

        1) Solids-liquid separation

        2) Solids concentration

    5. Nutrient Availability

      a. N

      b. P

KEY POINTS & INSTRUCTOR GUIDE

Instructor should be thoroughly familiar with the content of Unit 11, Lesson 1.

Use Slide 179.2/11.2.1
Slide 179.2/11.2.1 is a blank

Refer to Lesson 1 of this unit for detailed discussion of items covered in the Introduction

All slides in this lesson are available as print masters to make overhead transparencies.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

        c. Fe
        d. D.O.
    6. Toxic or inhibitory substances
    7. Mixing
B. Activated Sludge Controllable Variables
    1. Return Sludge Flow Rate
    2. Waste Sludge Flow Rate
    3. Air Application Rate
    4. Aeration Volume
        a. Volume used for aeration
        b. Contacting Mode (sludge reaeration capability)
    5. Addition of Chemical Additives
    6. Sewer Use Control
        a. Source control
        b. Equalization
C. Objective in Activated Sludge Treatment
    1. Convert non-settleable BOD to settleable solids
    2. Remove excess settleable solids from system and dispose of them properly
    3. Maintain good sludge quality which will accomplish 1 and 2
D. Purpose of this Lesson

LESSON OUTLINE

1. Identify parameters which should be monitored to evaluate, troubleshoot or control the activated sludge process
2. Identify how the monitored parameters are interpreted to determine process condition
3. Identify how monitored parameters are interpreted to determine changes in the controllable variables to maintain process conditions which produce good quality effluent

II. Final Clarifier Operational Strategies

A. Purpose of Activated Sludge Process Components

1. Most biological reactions occur in aeration tank with little additional biological reaction occurring in the final clarifier
2. Final clarifier is used to
    a. Separate activated sludge solids (MLSS) from the liquid (effluent) stream by gravity settling (clarification function)
    b. Concentrate activated sludge solids before they are returned to the process or wasted (thickening function)

B. Two Strategies for Operating Final Clarifier

1. Use as a solids storage reservoir
    a. Allow activated sludge solids to accumulate in final clarifier when they are not needed in the aeration basin

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.2.2

Slide 179.2/11.2.2 is a schematic diagram of an activated sludge process showing the aeration tank, the final clarifier, return sludge line, waste sludge line, effluent line and influent line

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

b. Reduce quantity of solids stored in final clarifier when additional solids are needed in the aeration basin

c. Allow solids to accumulate in the final clarifier by reducing

1) Return sludge flow rate

2) Waste sludge flow rate

d. Remove solids from the final clarifier by increasing

1) Return sludge flow rate

2) Waste sludge flow rate

2. Maintain constant solids inventory in the final clarifier

a. Adjust clarifier underflow rate as necessary so that solids withdrawn from the clarifier equals the mixed liquor solids entering the clarifier

b. When influent MLSS to clarifier increases, then increase return and/or waste rate to maintain clarifier solids inventory constant

c. When influent MLSS to clarifier decreases, then decrease return and/or waste rate to maintain clarifier solids inventory constant

3. The final clarifier operating stragety used will determine how the activated sludge system (aeration basin plus final clarifier) responds to changes in return sludge flow rate and waste sludge flow rate

LESSON OUTLINE

a. Final clarifier as solids storage reservoir

   1) Increased wasting removes solids from the solids reservoir in the final clarifier with little or no effect on the quantity of solids in the aeration basin

   2) Increased return moves solids from the final clarifier to the aeration basin increasing the quantity of solids in the aeration basin.

      a) The MLSS concentration increases

      b) The final clarifier sludge blanket falls

KEY POINTS & INSTRUCTOR GUIDE

Note: Eventually the reservoir would be depleted. At that time MLSS would begin to decrease

Note:

1. Initial increase in return rate causes the aeration basin MLSS concentration to increase only slightly. Thus, initially the quantity of solids being recycled to the head of the aeration basin will be greater than the quantity leaving the aeration basin and entering the final clarifier.

2. Eventually, the aeration basin MLSS concentration will reach a new steady state so that the quantity of solids recycled to the aeration basin equals the quantity being discharged from the basin

   a. In a plug flow basin this would occur in a time equal to one aeration basin hydraulic detention time

   b. In a complete mixing system, the aeration basin effluent solids would be about 2/3 the aeration basin influent solids in one aeration basin detention time and the new steady state would be reached in about three

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	aeration basin hydraulic detention times
3) Decreased wasting causes solids to accumulate in the reservoir in the final clarifier with little or no effect on the quantity of solids in the aeration basin	Note: Eventually, this condition would lead to the final clarifier filling with solids with subsequent overflow and wash-out of solids into the final effluent unless return rate or waste rate were increased before wash-out occurs
4) Decreasing return rate would cause solids to accumulate in the final clarifier reducing the quantity of solids in the aeration basin a) The MLSS concentration decreases b) The final clarifier sludge blanket rises	Note: 1. Eventually this could cause the same problem described in the Note for Item 3 2. If sufficient storage capacity exists in the final clarifier so that wash-out does not occur, the aeration basin-final clarifier system will reach a new steady state in which the quantity of solids recycled to the aeration basin equals the quantity being discharged from the basin
b. Constant solids inventory in the final clarifier 1) Initially, changes in return rate cause effects on aeration basin MLSS similar to those described in a. above but the effect is only temporary 2) Eventually, the system reaches a new steady state which shows no change in the quantity of solids in the aeration basin or final clarifier	

        3) This occurs because the solids settling and compaction rates change
            a) Increasing return causes the solids to settle more slowly
            b) Decreasing return causes the solids to settle faster
        4) A similar effect on settling rate occurs with changes in wasting rate
            a) Increasing wasting rate causes the solids to settle more slowly
            b) Decreasing wasting causes the solids to settle faster

C. Process Conditions Necessary for Implementing Final Clarifier Operating Strategies

  1. To operate with final clarifier as a solids storage reservoir
      a. Must have a sludge blanket
      b. Must have a fast settling, well stabilized sludge which concentrates well
          1) Normally associated with low F/M
          2) Normally associated with a long MCRT
          3) Normally associated with a low MLSS Respiration Rate (RR)

Note to Instructor: System Response Time

a) System responds to changes in return rate quickly. The effect of a return rate change will be observed in a time less than the hydraulic detention time in the aeration basin.

b) System responds to changes in wasting rate more slowly. The effect of a change in wasting rate (solids inventory) will require a time equal to approximately one MCRT for the response in settling rate to be observed.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

4) Normally associated with relatively long sludge aeration times

c. Rationale

1) Sludge must be well stablized so that sludge settling rates do not change appreciably with changes in return rate, waste rate, organic load or hydraulic load

2) Sludge must be fast settling so that it moves into sludge blanket and sludge compression zones quickly

3) Sludge must concentrate well so that changes in the quantity of sludge in the final clarifier do not cause large changes in sludge blanket depth

d. Advantages

1) System operates with relatively old sludge and is relatively insensitive to changes in influent conditions

2) Solids reservoir available to respond to changes in applied load

3) Sludge settles rapidly and concentrates well preventing wash-out from final clarifier

4) Relatively simple process control because process is insensitive to change

5) Well stabilized effluent normally low in soluble BOD_5

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

6) Good nitrification potential

e. Disadvantages

1) System is very insensitive to process control changes

2) Older, well stabilized sludges tend to yield turbid effluents because of ashing and poor flocculation characteristics making it difficult to meet NPDES solids limits

3) Sludge retention in final clarifier creates risk of problems such as denitrification and septic sludge which could cause clumping or floating sludge problems

2. To operate with a constant solids inventory in the final clarifier

a. Final clarifier sludge blanket is preferred but not essential

b. Sludge must have a slow to moderately fast settling sludge which is not fully stabilized

1) Normally associated with good sludge quality as defined by West

2) Frequently associated with sludges produced in a conventional plug flow activated sludge plant

a) F/M in range 0.3-0.5
b) MCRT in range 5-8 days
c) Aeration detention time in range 4-8 hours
d) Respiration rate in range 12-16 mg O_2/hr/gm

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
c. Rationale	
1) Sludge must be responsive to control changes to prevent accumulation in the final clarifier, if operating with a final clarifier sludge blanket.	
2) Moderately stable sludges show a sensitivity to changes in	
a) Return rate	
1 Increase return causes decrease in settling rate and increase in respiration rate	Note: Return rate control is a short term control response (system response time on the order of the aeration basin hydraulic detention time)
2 Decrease return causes increase in settling rate and decrease in respiration rate	
b) Waste rate	
1 Increase wasting causes decrease in settling rate and increase in respiration rate	Note: Solids Inventory Control is a long term control response (system response time on the order of the MCRT)
2 Decrease wasting rate causes increase in settling rate and decrease in respiration rate	
c) Organic load	
1 Increase causes a decrease in settling rate and an increase in respiration rate	Note: Short system response time on the order of the aeration basin hydraulic detention time

LESSON OUTLINE

2 Decrease causes an increase in settling rate and a decrease in respiration rate

d) Hydraulic load

1 Increase causes a decrease in settling rate and a decrease in respiration rate

2 Decrease causes an increase in settling rate and a decrease in respiration rate

d. Advantages

1) System is very responsive to a wide range of process control changes

2) System produces excellent effluent

a) Low TSS

b) Low BOD_5

3) System is responsive to influent changes permitting early response to changing conditions

e. Disadvantages

1) Because system is responsive to influent and process control changes, it must be closely monitored and controlled

2) Greater potential for solids wash-out in final clarifier because sludge settles more slowly

KEY POINTS & INSTRUCTOR GUIDE

Note: System response time is on the order of the aeration basin hydraulic detention time.

LESSON OUTLINE

D. Activated Sludge Process Control and Troubleshooting techniques developed in this course will be based on the West model which assumes that the final clarifier is operated to maintain a constant solids inventory

   1. Return and waste rates are adjusted to remove solids at a rate equal to the solids loading to the final clarifier

   2. The system is operated with a moderately stable, relatively fast settling sludge because

      a. Such sludges produce the best quality effluent

      b. The system is responsive to process control changes

III. Process Control Parameters (25 minutes)

A. Identify Process Control Parameters

   1. List parameters to be presented

      a. F/M
      b. MCRT
      c. D.O.
      d. Detention time
         1) Hydraulic detention time
         2) Sludge aeration time
      e. Sludge settling characteristics (also known as Mallory, West or Sludge Quality Control Techniques)
      f. OUR or RR

   2. Refer class to pages T11.2.1 - T11.2.5 in the *Trainee Notebook.* This handout briefly describes and discusses the advantages and disadvantages of the several process control parameters

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.2.3

Slide 179.2/11.2.3 is a word slide which reads:

"Activated Sludge Process Control Parameters

A. Food to Microorganism Ratio (F/M)
B. Mean Cell Residence Time (MCRT)
C. Dissolved Oxygen Concentration
D. Aeration Detention Time
   1. Hydraulic Detention Time
   2. Sludge Aeration Time
E. Sludge Settling Characteristics
F. Oxygen Uptake or Respiration Rates (OUR or RR)"

LESSON OUTLINE

B. Dissolved Oxygen Concentration

1. Maintain about 2 mg/l D.O. in aeration basin
    a. Less than 2 mg/l potential septic conditions
    b. Greater than 2 mg/l not economical
    c. Excessive D.O. (greater than 5 mg/l) may cause over-oxidation and floc shear problems
2. Probe aeration tank to assure that there are no dead spots (D.O. less than 1 mg/l)
    a. Dead spots are inactive
    b. Dead spots may become septic
    c. May indicate inadequate mixing
    d. May indicate need to taper the air supply
3. Carry sufficient D.O. in aeration tank effluent to keep final clarifier aerobic. Should have some detectable level of D.O. in return sludge
    a. Potential denitrification
    b. Potential floating sludge problem
4. Aeration equipment provides aeration tank mixing energy. May have to carry D.O. greater than 2 mg/l to maintain adequate mixing.
    a. Potential dead spots
    b. Potential sludge deposition in aeration tank

KEY POINTS &
INSTRUCTOR GUIDE

Use Slide 179.2/11.2.4

Slide 179.2/11.2.4 is a word slide which reads:

"Dissolved Oxygen Control

1. Maintain 2 mg/l
2. D.O. Throughout Aeration Tank
3. Avoid Septic Conditions in Clarifier
4. Adequate Mixing"

LESSON OUTLINE

c. Poor contact between sludge and wastewater

C. Solids Inventory

1. Most activated sludge control strategies are based on identifying the solids inventory which gives the best effluent quality and then maintaining that solids inventory

2. Solids inventory is the total pounds of activated sludge solids in the system

a. Includes solids in aeration tank(s) plus solids in reaeration tank(s) plus solids in final clarifier(s)

b. Best if measured as VSS but can be estimated as TSS or by centrifuge spin tests (% solids by centrifuge)

c. Some plants have used COD, TOC or TOD of solids to estimate the solids inventory

3. Calculation of Solids Inventory

a. Solids in aeration or reaeration basin

1) Formula

$$\# \text{ Solids} = \underset{(\text{MG})}{\text{Vol of Tank}} \times \underset{(\text{mg/l})}{\text{Solids Conc.}} \times 8.34$$

2) Units

MG = Million gallons

mg/l = Milligrams per liter

8.34 = Units Conversion factor

KEY POINTS &
INSTRUCTOR GUIDE

Use Slide 179.2/11.2.5

Slide 179.2/11.2.5 is a word slide which reads:

"Solids in Aeration or Reaeration Tank

$$\# \text{ Solids} = \underset{(\text{MG})}{\text{Vol of Tank}} \times \underset{(\text{mg/l})}{\text{Solids}} \text{ Conc.} \times 8.34"$$

LESSON OUTLINE

b. Solids in final clarifier

1) Formula

$$\# \text{ Solids} = \underset{(MG)}{\text{Vol of Clarifier}} \times \underset{(mg/l)}{\text{Ave Solids Conc}} \times \frac{\text{Sludge Blanket Thickness (ft)}}{\text{Ave Depth of Clarifier (ft)}} \times 8.34$$

2) Average Solids Concentration =

$$\frac{\text{Mixed Liquor Conc} + \text{Return Sludge Conc}}{2}$$

3) Sludge blanket thickness is equal to the distance from the top of the sludge blanket to the bottom of the final clarifier (the final clarifier average depth)

4) Units

MG = million gallons

mg/l = milligrams per liter

ft = feet

8.34 = Units conversion factor

c. Total solids inventory equal to the sum of the aeration tank solids plus the reaeration tank solids plus the final clarifier solids

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.2.6

Slide 179.2/11.2.6 is a word slide which reads:

"Solids in Final Clarifier

$$\#\text{Solids} = \underset{(MG)}{\text{Vol of Clarifier}} \times \underset{(mg/l)}{\text{Ave. Solids Conc}} \times \frac{\text{Sludge Blanket Thickness (ft)}}{\text{Ave Depth of Clarifier (ft)}} \times 8.34$$

Average Solids Concentration =

$$\frac{\text{Mixed Liquor Conc} + \text{Return Sludge Conc}}{2}$$ "

Refer class to *Trainee Notebook* page T11.2.6 - T11.2.8 for a summary of calculation procedures

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. Solids Inventory Control	
a. Solids inventory is controlled by wasting	
1) Deliberate wasting - waste activated sludge pumped out of the system to solids conditioning and disposal	
2) Unintentional wasting - solids lost in the final effluent	
b. To decrease solids inventory, increase wasting	
c. To increase solids inventory, decrease wasting	
d. Changing the return sludge rate does not affect the solids inventory	
4. The correct solids inventory for a given plant must be determined empirically	
a. Operate plant at various solids inventories, then select the solids inventory which gives the best effluent quality as the desired operating point for the plant	
b. F/M, MCRT, RR and sludge settleability control parameters can be used to "hone in" on the correct solids inventory by eliminating a lot of trial and error guessing	
D. Constant Mixed Liquor Suspended Solids Control	Use Slide 179.2/11.2.7 Slide 179.2/11.2.7 is a blank
1. A "Quick and Dirty" approach to achieve solids inventory control	Refer class to handout, *Trainee Notebook*, page T11.2.2

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

2. Ignores the solids in the final clarifier

3. Procedure

   a. Determine MLSS which gives the best effluent

   b. Measure MLSS each day

      1) Sample at same point each day

      2) Sample at same time each day (usually at peak flow)

   c. Calculate wasting necessary to maintain MLSS at desired value

4. Advantages

   a. Simple

   b. Minimum laboratory testing required

5. Disadvantages

   a. Does not include clarifier solids

   b. Does not consider load changes

      1) Organic

      2) Hydraulic

   c. MLSS may vary greatly with changes in influent hydraulic load or return sludge rate

   d. Does not consider changes in sludge settleability (sludge quality)

   e. Gives inconsistent control because of above problems

E. Aeration Detention Time
   1. Effect on Sorption Reactions

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
a. Need sufficient time to adsorb and absorb influent pollutants	
1) Adsorption complete in 30-90 minutes contact	
2) Absorption usually completed in 4-6 hours contact	
b. Need adequate mixing to promote contact between sludge solids and wastewater	
2. Effect on stabilization reactions	The term sludge stability is used to characterize the completeness of the metabolic reactions
a. Metabolic reactions to stabilize waste and create new growth of sludge solids slower than sorption reactions	Unstable - still actively metabolizing waste or internal storage products
1) For domestic wastes stabilization is normally complete in 6-8 hours	Stable - metabolic reactions essentially complete but still active biologically
2) For some industrial wastes, e.g., brewry wastes, may need 16-24 hours to complete stabilization	Over Stabilized - sludge is well into endogenous phase of growth
b. Stability of sludge affects flocculation and settling characteristics	
1) "Unstable" sludges (high F/M, short aeration time) tend to be flocculent, settle slowly, do not compact well (2-4 hours to ultimate compaction) but produce clear effluents	Extreme case is dispersed growth. Less extreme is classic sludge bulking
2) "Stable" sludges (moderate F/M, 6-8 hours aeration time) tend to flocculate well, settle fairly rapidly, concentrate well (about 60 minutes for	Stable sludges are most desirable and have good sludge quality

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
ultimate compaction) and produce clear high quality effluent	
3) "Over stabilized" or "over oxidized" sludges (low F/M, greater than 8 hours aeration time) tend to be less flocculent, settle rapidly, concentrate quickly (ultimate compaction in 30 minutes or less) and leave excess solids in the effluent	Characteristic sludge for an extended aeration plant
3. Two aeration detention times of interest	
a. Hydraulic detention time in aeration basis	
1) Measure of the time the wastewater is in contact with sludge solids in the aeration basin	
2) Mathematical definition	
a) Based on influent flow	
$\theta_h = \frac{\text{Aeration Basin Volume}}{\text{Influent Flow Rate}}$	Write equations on chalkboard
b) Based on total flow to aeration basin	
$\theta_h = \frac{\text{Aeration Basin Volume}}{\text{Influent + Return Sludge Flow Rate}}$	
3) Increasing return sludge flow rate or influent flow rate reduces hydraulic detention time in the aeration basin	
4) Effect of changes in hydraulic detention time	Use Slide 179.2/11.2.8 Slide 179.2/11.2.8 is a word slide which reads:

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
a) Decrease hydraulic detention time will reduce time for stabilization and will cause sludge to become less stable	"Activated Sludge Process Control Effect of Aeration Detention Time Decrease — Less Stable Sludge Slower Settling Rate Concentrates slower
b) Increase hydraulic detention time will increase time for stabilization and will cause sludge to become more stable	Increase — More Stable Sludge Faster Settling Rate Concentrates Faster"
b. Sludge aeration detention time	
1) Sludge concentration in and recycles from the final clarifier causes the sludge to remain in the system longer than the influent wastewater entering the aeration basin. Thus, sludge detention time is greater than the aeration basin hydraulic detention time	
a) Increasing sludge aeration detention time increases sludge stability	Reiterate the relationship between sludge stability and and sludge settling characteristics
b) Decreasing sludge aeration detention time decreases sludge stability	
2) Methods to change sludge aeration detention time	
a) Increase the solids inventory	
b) Use sludge reaeration	
1 Contact stabilization 2 Two-stage aeration 3 Step Feed	
3) Relationship to solution of	

LESSON OUTLINE

sludge settling (sludge quality) problems

- a) To make a slow settling sludge settle faster, increase sludge aeration detention time
- b) To make a faster settling sludge settle more slowly, decrease sludge aeration detention time

4. Process Control Based on Detention Time

   a. Some plants use aeration basin hydraulic detention time as the principal process control tool

      1) Increase or decrease return rate as influent flow rate changes to maintain constant flow to aeration basin. Must be coupled with constant MLSS control

      2) Advantages

         a) Simplicity

      3) Disadvantages

         a) Potential to overload clarifier at peak flow

         b) Does not consider changes in influent organic load

         c) Does not consider effects of MCRT or F/M changes

         d) Does not consider changes in sludge settleability (sludge quality)

KEY POINTS &
INSTRUCTOR GUIDE

Use Slide 179.2/11.2.9

Slide 179.2/11.2.9 is a word slide which reads:

"Activated Sludge Process Control

Effect of Sludge Aeration Time

Decrease	Less Stable Sludge Slower Settling Rate Concentrates Slower
Increase	More Stable Sludge Faster Settling Rate Concentrates Faster"

LESSON OUTLINE

e) Works best in underloaded plants with relatively constant influent waste characteristics

b. Most useful as troubleshooting tool

1) Solve sludge quality (sludge settleability) problems

2) Respond to large variations in influent waste characteristics

F. Food to Microorganism Ratio (F/M)

1. Define F/M

a. $F/M = \frac{\#BOD_5 \text{ Applied per day}}{\#\text{Solids Inventory}}$

b. $\#BOD_5$ applied per day is total load fed to aeration basin

1) Influent load

2) Loads caused by internal recycles, e.g.

a) Digester supernate

b) Filtrates

c) Heat Treatment Liquors

3) May measure applied load as COD, TOC, TOD, etc.

c. #Solids Inventory is all solids in activated sludge system

1) Includes

a) Aeration Basin Solids

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.2.10

Slide 179.2/11.2.10 is a word slide which reads:

"Food to Microorganism Ratio (F/M)

$F/M = \frac{\#BOD_5 \text{ Applied Per Day}}{\# \text{ Solids Inventory}}$ "

LESSON OUTLINE

        b) Reaeration Basin Solids

        c) Final Clarifier Solids

    2) Measured as

        a) VSS preferred as best measure of activated sludge solids

        b) TSS alternate but subject to problems because volatile fraction changes

        c) Centrifuge spins can be used to estimate solids but subject to variations as solids compaction characteristics and volatile fraction changes

        d) TOD, TOC, COD, etc. could be used to estimate solids

2. Describe use of F/M

    a. Balances solids to incoming load

    b. High F/M = unstable, overloaded system, higher WAS production, less stable sludge, slower settling sludge, low nitrification potential

    c. Low F/M = underloaded system, lower WAS production, more stable sludge, faster settling sludge, high nitrification potential

3. Give typical ranges for F/M

    a. Conventional = 0.2-0.5

    b. Step aeration = 0.2-0.5

    c. Contact stabilization = 0.15-0.2

KEY POINTS & INSTRUCTOR GUIDE

Note to Instructor: All units are $\frac{\# \text{ BOD}_5 \text{ Day}}{\# \text{ VSS}}$

Best F/M is plant specific and must be determined empirically by operating over range of F/M values and selecting range which gives best effluent quality.

   d. Two stage aeration = 0.07-0.15

   e. Extended aeration = 0.01-0.07

4. List limitations of F/M Control

   a. Best used as a moving average (5 or 7-day) to balance out wide daily fluctuations

   b. Must make certain that food and microorganisms are estimated right (that is, is food tested by BOD, COD, TOC, etc.?)

   c. Best used in conjunction with other control parameters

      1) MCRT

      2) Sludge quality

      3) Respiration Rate (RR)

   d. Time delay when food measured as BOD_5

   e. Does not consider changes in influent flow rate

   f. Does not consider changes in sludge quality

5. Controlling F/M

   a. Control parameter to maintain correct solids inventory

   b. Change solids inventory by increasing or decreasing WAS rates

   c. Changes in return sludge rate have no effect on F/M as defined for this course

G. Gould Sludge Age (GSA)

1. Define GSA

Use Slide 179.2/11.2.11

LESSON OUTLINE

a. $$\text{GSA} = \frac{\#\ \text{Solids Inventory}}{\#\ \text{Primary Effluent Suspended Solids/Day}}$$

b. # Solids Inventory

   1) Aeration basin

   2) Reaeration basin

   3) Final clarifier

c. # Primary effluent suspended solids per day is the suspended solids applied to the aeration basin each day

d. Consistent units must be used

2. Really an inverse F/M where food is estimated by influent suspended solids

3. A major limitation is the assumption that influent suspended solids is an accurate measure of influent organic load

4. Uses and limitations are similar to those given for F/M

5. Control GSA by varying solids inventory. Vary solids inventory by changing the waste rate

6. Gould Sludge Age should not be confused with MCRT. They are not the same

H. Mean Cell Residence Time (MCRT)

   1. Define MCRT

      a. The time in days that the average unit of sludge remains in the system

KEY POINTS & INSTRUCTOR GUIDE

Slide 179.2/11.2.11 is a word slide which reads:

"Gould Sludge Age

$$\text{GSA} = \frac{\#\ \text{Solids Inventory}}{\#\ \text{Primary Effluent Suspended Solids/Day}}\text{"}$$

Use Slide 179.2/11.2.12

Slide 179.2/11.2.12 is a word slide which reads:

"Mean Cell Residence Time (MCRT)

$$\text{MCRT} = \frac{\#\ \text{Solids Inventory}}{\#\text{Solids Wasted Per Day}}\text{"}$$

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. $MCRT = \frac{\#\text{Solids Inventory}}{\#\text{ Solids Wasted Per Day}}$	
1) # Solids Inventory is all solids in the system	
a) Aeration solids	
b) Reaeration solids	
c) Final clarifier solids	
2) # Solids wasted per day is all solids removed from the system	
a) Deliberate waste as WAS	
b) Unintentional waste as effluent suspended solids	
3) Use consistent units. Volatile suspended solids is the preferred unit	
2. List Uses of MCRT	
a. Control solids inventory	
b. Determine WAS rates	
c. Determine the type of microorganisms that predominate	Microbiology of activated sludge is discussed in Lesson 4, Unit 11
d. Affect sludge stability	
1) Long MCRT = stable sludge	Long MCRT increases nitrification potential
2) Short MCRT = less stable sludge	
3. Give typical ranges of MCRT	
a. Conventional = 4-8 days	
b. Step aeration = 4-8 days	
c. Contact stabilization = 8-10 days	

LESSON OUTLINE

- d. Two-stage aeration = 10-15 days
- e. Extended aeration = 10-30 days

4. List limitations of MCRT
   - a. Best used in conjunction with other control parameters, such as F/M, sludge quality and RR
   - b. Provides best results as a moving average to balance out daily fluctuations
   - c. Temperature related
     - 1) Decrease temperature, increase solids inventory and MCRT
     - 2) Increase temperature, decrease solids inventory and MCRT
   - d. Best used as a long term control to maintain solids inventory
   - e. Does not consider organic or hydraulic load changes
   - f. Does not consider sludge quality.
5. MCRT is controlled by varying solids inventory. Control solids inventory by varying WAS
6. MCRT is sometimes called sludge retention time (SRT)

I. Respiration Rate (RR)

1. Define RR
   - a. The specific oxygen uptake rate
   - b. $RR = \frac{\text{mg/hr oxygen used}}{\text{gram MLSS}}$

KEY POINTS & INSTRUCTOR GUIDE

Best MCRT is plant dependent. Must determine best solids inventory experimentally by operating at several MCRTs and selecting MCRT that gives best treatment

Use Slide 179.2/11.2.13

Slide 179.2/11.2.13 is a word slide which reads:

"Respiration Rate (RR)

$RR = \frac{\text{mg/hr Oxygen Used}}{\text{Gram MLSS}}$"

LESSON OUTLINE

2. Principle Uses of RR

   a. Measure sludge stability. RR of of aeration basin effluent suspended solids can be correlated with settling characteristics and sludge or effluent stability

      1) Low RR = Old, very stable, fast settling sludge. Usually associated with low F/M and long MCRT

      2) RR in range 12-20 mg/hr/gm is associated with good sludge quality and good effluent quality

      3) High RR = young, unstable, slow settling sludge. Usually associated with high F/M and short MCRT

   b. Measure effluent stability

      Oxygen uptake test can be done on undiluted final effluent to estimate BOD_5 (takes approximately 1-4 hours)

   c. Measure of influent load

      RR of a mixture of influent wastewater and return activated sludge can be used as an indicator of influent oxygen demand. Also, can be used to evaluate waste treatability and to detect presence of toxic or inhibitory substances

   d. Interpretation of respiration rate test results can be used to

      1) Indicate need to increase or

KEY POINTS &
INSTRUCTOR GUIDE

Note to Instructor: Respiration rate determination and interpretation will be covered in detail in Lesson 6, Unit 11

LESSON OUTLINE

decrease return sludge rates

2) Indicate need to increase or decrease solids inventory

3) Indicate when sludge reaeration should be used to increase stability or when reaeration should be discontinued

3. Respiration rate provides powerful tool to supplement other control parameters such as F/M, MCRT, and sludge quality

J. Sludge Quality Control (Al West Procedures)

1. Principal tool is observation and recording of MLSS settling and compaction characteristics

2. Settleometer or similar vessel is used to monitor settling characteristics - simulates what happens in the clarifier

3. Settleometer observations are coupled with measurement of MLSS, RSC and XSC and influent, return and waste sludge flow rates

4. Results are interpreted to control:

    a. Return sludge flow rate
    Calculation procedures based on final clarifier solid balance are used to define return rate to maintain or improve sludge quality

    b. Waste sludge rate
    Settleometer observations can be used to indicate need to increase or decrease wasting. Exact changes can be determined using other control tests and parameters

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.2.14

Slide 179.2/11.2.14 is a word slide which reads:

"Settleable Solids
Sludge Quality

GOOD

- Settles Fairly Rapidly
- Concentrates Uniformly - 30 to 60 minutes
- Flocculent
- Clear Supernate
- Deep Tan to Brown

BAD

- Settles Very Fast or Very Slowly
- Concentrates Very Rapidly (30 minutes) or Very Slowly (2-4 hours)
- Granular or Excessively Fluffy
- Cloudy, Turbid, Straggler Floc, Pin Floc or Ashing
- Light Tan, Very Dark Brown or Black"

LESSON OUTLINE

5. Settleometer observations indicate activated sludge process conditions
   a. Slow settling - high F/M, short MCRT, short detention time, high RR (less stable sludge)
   b. Fast settling - low F/M, long MCRT, long detention time, low RR (stable sludge)
6. Sludge quality control observations are essential adjunct to other process control parameters such as F/M, MCRT and RR

K. Visual Observations

1. Regular periodic inspection of the plant and process is essential part of an overall process management scheme
2. Visual observations to be made include:
   a. Aeration tank
      1) Foam - quantity, color and type
      2) Sludge solids - color and odor
      3) Mixing adequacy
      4) Adequate aeration
   b. Final clarifier
      1) Surface appearance
      2) Sludge blanket
      3) Hydraulic effects
3. Visual observations are indicators of potential problems

KEY POINTS & INSTRUCTOR GUIDE

Note to Instructor: Sludge quality control procedures and interpretations of results will be covered in detail in Lesson 5, Unit 11

Use Slide 179.2/11.2.15
Slide 179.2/11.2.15 is a blank

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

4. Visual inspection of activated sludge systems and interpretation of the observations for process control and troubleshooting will be covered in Lesson 8, Unit 11

L. Use of Control Parameters in Process Control and Troubleshooting

1. Information from control parameters
    - a. F/M
        - 1) Balance between influent load and solids inventory
        - 2) Adequacy of solids inventory
            - a) Too many solids
            - b) Too few solids
    - b. MCRT
        - 1) Monitor and control solids inventory
        - 2) Adequacy of solids inventory
            - a) Too old a sludge - increase wasting
            - b) Too young a sludge - decrease wasting
    - c. RR
        - 1) Stability of sludge solids and effluent, i.e., increase aeration or decrease aeration time

LESSON OUTLINE

KEY POINTS &
INSTRUCTOR GUIDE

2) Adequacy of return rate, i.e., increase return or decrease return

3) Adequacy of solids inventory, i.e., too many solids or too few solids

4) Waste characteristics, i.e., load changes or toxic or inhibitory substances

d. Sludge Quality (Sludge Settleability)

1) Indicate solids separation and clarification characteristics in final clarifier

a) Settling too fast

b) Settling too slow

c) Produce clear effluent

2) Adequacy of sludge aeration time

a) Increase aeration time

b) Decrease aeration time

3) Optimum return sludge rate

a) Amount to increase return

b) Amount to decrease return

4) Adequacy of solids inventory

a) Solids quantity

1. Too many
2. Too few

b) Solids age

1. Too old
2 Too young

857

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

2. Each control parameter gives different information about the process. No single parameter gives complete information. Therefore, it is recommended that all four parameters be monitored so that control decisions are based on complete process information:

   a. F/M

   b. MCRT

   c. RR

   d. Sludge Quality (Sludge Settleability)

   This permits optimizing the system performance by maintaining

   a. Correct solids inventory
   b. Proper return sludge rates
   c. Proper wasting rates
   d. Adequate aeration time

3. Use of controllable variables

   a. Return sludge rate is a short term control used to optimize and maintain process balance during the operating day - changes in return rate will affect the process very quickly (2-4 hours)

   b. Wasting is a long term control used to maintain sludge inventory. Wasting changes cause slow responses in the system and several days may be needed before any response is observed

4. Major use of parameters

   a. Determine return sludge control adjustments

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
1) Sludge quality	
2) RR	
b. Determine waste sludge control adjustments	
1) MCRT	
2) F/M	
3) Sludge quality and RR rate will indicate whether to increase or decrease wasting	
c. Determine sludge aeration detention time adjustments (process mode changes)	
1) Sludge quality	
2) RR	
IV. Trend Charts (5 minutes)	
A. Daily changes in parameters	Refer class to: A. West, *Operational Procedures for the Activated Sludge Process*, Appendix for illustrations of trend charts and calculations of moving averages
1. Daily fluctuations in organic load will cause daily change in F/M	
2. Daily fluctuations in waste sludge rate will cause daily changes in MCRT	
3. Daily fluctuations in F/M or MCRT may be very large	
4. Responding to instantaneous values of F/M or MCRT could cause serious process stability problems because of severe over or under wasting	
5. Therefore, operator and troubleshooter should respond to long term trends for effective control of solids inventory and wasting rates	

LESSON OUTLINE

KEY POINTS &
INSTRUCTOR GUIDE

B. Moving Average

1. F/M and MCRT should be reduced to five- or seven-day moving averages

2. Refer class to West, *Operational Control Procedures for the Activated Sludge Process*, *Appendix*, page 7, and explain calculation of the moving average

C. Trend Charts

1. Daily and moving average values of operating parameters should be graphed daily

2. At least 30 days of prior operational data should appear on the graph

3. Graphing of control data makes detection of trend changes easier

4. Refer class to West, *Operational Control Procedures for the Activated Sludge Process*, *Appendix*, page 2 and explain how trend charts are prepared and used.

D. Wasting Rate Control, in particular, should be based on trend data and not on daily observations of process parameters

E. Return rate control can be based on individual observation of RR and sludge quality because this is a short term control used to maintain process balance and to optimize performance

V. Summary and Discussion (5 minutes)

A. Review Key Points

1. Process control parameters F/M, MCRT, RR and Sludge Quality

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

2. Controllable variables

   a. Wasting - long term control of sludge inventory. Wasting changes should be made slowly. Change waste rates no more than 15 per day. Determine wasting changes with F/M and MCRT

   b. Return sludge - short term control for process balance. Determine return changes with RR and sludge quality

   c. Air - maintain at least 2 mg/l D.O. and adequate mixing

   d. Sludge aeration volume - change mode to reaeration to increase sludge stability

3. Trend charts and moving averages

B. Discussion

Use remaining time to respond to questions from the class

C. Class Assignment

1. Read *Operators Pocket Guide to Activated Sludge, Parts I and II*

2. Read *Operational Control Procedures for the Activated Sludge Process, Parts I, II and Appendix* and *Updated Summary*

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 2: Process Control Concepts for Activated Sludge

Trainee Notebook Contents

Activated Sludge Process Control Parameters. . . . T11.2.1

Calculation of Control Parameters T11.2.6

ACTIVATED SLUDGE PROCESS CONTROL PARAMETERS

A. Food to Microorganism Ratio (F/M)

1. F/M is defined as the pounds of BOD applied per day per pound of suspended solids in the aeration basin and clarifier. Can also define in terms of other analyses such as COD, TOC, TOD, MLVSS, etc., but numbers will be different depending on the analyses used for process control. F/M control based on volatile suspended solids gives more consistent results than F/M control based on total suspended solids or on solids measured by centrifuge.

2. F/M attempts to balance the incoming food load and the mass of biological solids in the plant. Control is achieved by wasting activated sludge. Increased wasting increases the F/M. Decreased wasting decreases the F/M. F/M is a long-range control strategy to maintain a proper quantity of solids in the system. F/M provides limited information for making return sludge rate changes.

3. Disadvantage is the need to perform complex time-consuming analyses to calculate the F/M. Also, it provides limited information on the effects of changing hydraulic load. Works best when coupled with other control strategies such as MCRT, Respiration Rate and settleability.

4. The best F/M value to be used for process control must be determined for each plant individually. There is no universal number which applies to all plants although most conventional activated sludge plants operate best in the 0.2 - 0.5 lb BOD applied per lb solids inventory per day. The F/M for a particular plant must be determined experimentally by trying a series of F/M operating points and then selecting that F/M which gives the best effluent quality.

5. When using F/M control, it is best to base control change decisions on a 5- or 7-day moving average rather than the day-to-day values.

B. Mean Cell Residence Time (MCRT)

1. MCRT is defined as the time in days that an average cell remains in the clarifier and aeration basin. Calculated by dividing the total pounds of mixed liquor and clarifier solids by the pounds of solids wasted per day (wasted activated sludge plus effluent suspended solids). Volatile suspended solids is the preferred analysis for solids inventory although total suspended solids or centrifuge spins can be used to estimate solids inventory.

2. Advantages are that it requires only two laboratory measurements for suspended solids and is very easy to implement. MCRT is used to control the solids inventory and is adjusted by changing the amount of activated sludge wasted from the system. MCRT provides little information for making return sludge rate changes.

3. Disadvantages include failure to consider the organic or hydraulic loads to the system. Most effective when used in conjunction with the F/M, Respiration Rate and sludge settleability control concepts.

4. The best MCRT must be determined for each plant individually. The MCRT number used is the value which produces the best effluent quality. Most conventional activated sludge processes operate with an MCRT of 5 to 8 days; extended aeration MCRT may be as long as 15 to 30 days.

5. As with F/M, control decisions should be based on the 5- or 7-day moving average rather than on instantaneous day-to-day measurements.

6. MCRT is sometimes called the Sludge Retention Time (SRT).

C. Gould Sludge Age (GSA)

1. Sludge Age is defined as the pounds of suspended solids in the system divided by the pounds of suspended solids in the primary effluent per day.

2. Sludge Age is an empirical control parameter developed by Gould as a control parameter for his treatment plant.

3. GSA is similar to the reciprocal of the F/M where the aeration basin influent suspended solids (primary effluent suspended solids) is used to measure the food supply.

4. The GSA assumes that there is some constant relationship between primary effluent TSS or VSS and primary effluent BOD_5 which is a major limitation to this control parameter. If this assumption is valid for a particular waste, the GSA offers an alternate way to estimate F/M based on data which are more current than BOD_5.

5. Advantages and disadvantages are similar to those listed for the F/M.

D. Constant Mixed Liquor Suspended Solids (MLSS) or Constant Mixed Liquor Volatile Suspended Solids (MLVSS)

1. With this stragety, a MLSS or MLVSS concentration which produces a good effluent quality is determined and process control is achieved by holding the MLSS or MLVSS constant. Control is achieved by varying

the waste activated sludge rate. MLVSS is preferred because constant MLVSS gives more consistant control.

2. Advantage of the system is simplicity. One analysis is made at the same time each day and the quantity of sludge to be wasted is calculated and the waste rate adjusted accordingly.

3. Disadvantages to this strategy are many. It does not consider variations in organic or volumetric load. It does not consider solids in the clarifier. It requires that influent conditions be fairly constant from day to day and that samples be taken from the same point and at the same time each day. Many operators consider this to be among the most unreliable methods of process control.

4. MLSS or MLVSS concentration is controlled by varying the waste rate.

E. Respiration Rate (RR) or Specific Oxygen Uptake Rate

1. The RR is defined as the mg/hr of oxygen consumed per gram of MLSS or MLVSS. RR may be determined for several different sludge-raw wastewater or effluent mixtures as indicated below:

   a. Mixed liquor sample as it leaves the aeration basin.
   b. Return activated sludge diluted with final effluent.
   c. Return activated sludge diluted with primary effluent or raw wastewater.

   The RR of the mixed liquor sample leaving the aeration basin is most often used for process control.

2. There are many advantages to the RR as a control parameter.

   a. It gives a rapid measure of influent organic load and its biodegradability.
   b. It indicates the presence of toxic or inhibitory wastes.
   c. It indicates the condition of the return sludge.
   d. It indicates the degree of "stability" of the final effluent and the MLSS entering the final clarifier.
   e. It permits calculation of oxygen demand rates at various points in the aeration basin and hence closer control of air application rates.
   f. It provides information to control both return and waste rates.
   g. The RR test can be performed quickly and easily.

3. Disadvantages of the RR as a control strategy include:

   a. Several samples must be collected, analyzed and evaluated.
   b. The test procedure requires a dissolved oxygen meter and

gravimetric solids analyses. However MLSS or MLVSS may be estimated using centrifuge spins.

4. The best RR values must be determined for each plant individually. Mixed liquors leaving the aeration basin with a RR in the range 12-20 mg/O_2/hr/gm MLSS usually produce good BOD removal and a sludge which settles well.

5. RR provides information which permits control of both waste rate and return rate from the final clarifier. Some of the information which can be obtained from RR data includes:

   a. Increasing RR at the effluent of the aeration basin could indicate increasing organic load, increasing hydraulic load and lower aeration basin detention time, or decreasing MLSS (increasing F/M or decreasing MCRT). By combining this data with the RR data on the primary effluent and flow rate, appropriate decision to increase or decrease return and/or waste rates could be made.

   b. Decreasing RR at the effluent of the aeration basin could indicate decreasing organic load, decreasing hydraulic load, increasing aeration basin detention time or increasing MLSS (decreasing F/M or increasing MCRT). Again, looking at this RR and influent RR data, decisions on changes required in return or waste rates can be made.

6. RR control works best when combined with F/M, MCRT and sludge settleability control concepts.

F. Sludge Quality (Al West Control Procedures)

1. All process control strategies discussed above have a single objective: achieve and maintain good sludge quality which produces a highly purified effluent, settles well and concentrates in the final clarifier. Sludge quality control is based on observing the sludge settling characteristics to indicate needed changes in return sludge or waste activated sludge rates.

2. Sludge quality control concepts were pioneered by Mallory in the thirties and have been significantly advanced and improved by West. The pamphlet series included in your handout materials is an indepth discussion of sludge quality control as practiced by Mr. West. You should read and study these pamphlets carefully.

3. Sludge quality control is based on the concept that the sludge settling characteristics will change as activated sludge process conditions change. A change in influent organic load, influent hydraulic load,

sludge retention time in the aeration basin, MLSS concentration, return sludge flow rate, etc., will affect the settling and concentration characteristics of the sludge. The sludge settling rate and concentration rate are very sensitive indicators of changes in process condition and can be used to indicate process control actions needed to maintain good system performance. Combining the data from sludge settling and concentration measurements with the data from F/M, MCRT and RR control provides a very powerful tool to control the activated sludge process.

4. An advantage to sludge quality control is the simplicity of the test procedures. Settling rates are measured in a settleometer and concentrations of MLSS and return sludge are measured with the centrifuge. The complete testing series can be completed in about one hour. This permits the operator to do his tests more frequently and obtain better and more consistent control of the process.

G. Conclusion

1. All activated sludge process control strategies provide useful information which the operator can use to:

   a. Control the solids inventory in the plant. Solids inventory is controlled by adjusting the waste activated sludge rate.

   b. Control the distribution of solids between the clarifier and the aeration basin. Solids distribution is controlled by adjusting the return sludge rate.

   c. Control the sludge aeration time. Sludge aeration time is controlled by adjusting return sludge rate or by changing the aeration volume or the mixing pattern (process mode change).

2. Adjusting return sludge rate is a short term control used to maintain process balance. The effects of changes in return sludge on the process can be measured in only a few hours (time equal to about one-half the aeration detention time). Adjusting waste activated sludge rate is a long term control. The effects of changes in waste activated sludge rate can be measured after several days (a time equal to about half the mean cell residence time). Of the two, adjusting waste activated sludge rate to maintain a correct solids inventory is probably the more important to consistent long term control of the process. Return sludge control allows the operator to optimize the system's performance.

3. Each process control parameter provides different information to the operator. No single parameter tells the operator a complete story. The operator must combine information from several parameters to get a full picture and to be able to make the right process control decisions. The four parameters most useful to the operator are F/M, MCRT RR and sludge settleability.

CALCULATION OF CONTROL PARAMETERS

Formulas and Definitions

SOLIDS INVENTORY - The total quantity of activated sludge solids in the system. The solids inventory includes the solids in the aeration basin (mixed liquor solids), the solids in the final clarifier (sludge blanket solids) and the solids in the reaeration basin (two stage biological treatment and contact stabilization plants only).

Solids in the Aeration Basin

$$\text{Pounds of Solids in the Aeration Basin} = \text{Volume of Aeration Basin (million gallons)} \times \text{Mixed Liquor Solids Concentration (mg/l)} \times 8.34$$

If there are two or more aeration basins, calculate the pounds of solids in each basin separately. Then add the results to get the total pounds of aeration basin solids.

T11.2.6

Solids in the Final Clarifier

$$\text{Pounds of Solids in the Final Clarifier} = \text{Volume of Final Clarifier (million gallons)} \times \frac{\text{Sludge Blanket Thickness (ft)}}{\text{Final Clarifier Depth (ft)}} \times \text{Average Solids Concetration (mg/l)} \times 8.34$$

$$\text{Sludge Blanket Thickness (ft)} = \text{Final Clarifier Depth (ft)} - \text{Sludge Blanket Depth (ft)}$$

$$\text{Average Solids Concentration in Final Clarifier (mg/l)} = \frac{\text{Mixed Liquor Solids Concentration (mg/l)} + \text{Return Sludge Concentration (mg/l)}}{2}$$

Solids in Reaeration Basin

Pounds of Solids in the Reaeration Basin = Volume of Reaeration Basin (million gallons) x Concentration of Solids (mg/l) x 8.34

ORGANIC LOAD - The pounds of BOD_5* applied to the aeration basin per day

Organic Load (pounds/day) = Influent Flow Rate (MGD) x BOD_5 Concentration (mg/l) x 8.34

*Organic load may also be measured as COD, TOD, TOC or other units. Always measure the load the same way when calculating process control parameters. Include internal plant recycles in the applied load.

F/M - Food to microorganism ratio or the food to mass ratio. The pounds of organic load per day per pound of solids inventory. (Most consistent results are obgained when solids inventory is measured as volatile suspended solids but other units of solids inventory may be used.)

$$\text{F/M (pounds BOD}_5\text{ applied/day/pound solids inventory)} = \frac{\text{Organic Load (pounds BOD}_5\text{ applied/day)}}{\text{Solids Inventory (pounds)}}$$

MCRT - Mean Cell Residence Time. The average time that a unit of activated sludge solids remain in the system.

$$\text{MCRT (days)} = \frac{\text{Solids Inventory (pounds)}}{\text{Total Pounds Solids Lost Per Day}}$$

Total Pounds Lost Per Day = Pounds Solids Lost in Final Clarifier Effluent Per Day + Pounds Solids Deliberately Wasted Per Day

Pounds Solids in Final Effluent Per Day = Effluent Flow Rate (MGD) x Effluent Solids Concentration (mg/l) x 8.34

Pounds Solids Deliberately Wasted Per Day = Total WAS Flow (MGD) x WAS Concentration (mg/l) x 8.34

WAS = Waste Activated Sludge

If you waste from the return sludge line, then the WAS concentration equals the return sludge concentration (RSC).

SLUDGE UNIT - A dimensionless measure of solids used when MLSS, RSC and WSC are measured by centrifuge as percent solids

Sludge Unit = Volume (million gallons) x Concentration by Centrifuge (% solids)

Both solids inventory and solids lost per day can be expressed as sludge units

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 3: Activated Sludge Process Variations

Lesson 3 of 14 lessons Recommended Time: 25 minutes

Purpose: There are several variations of the activated sludge process. The most frequently used process variations are conventional, contact stabilization, extended aeration and step feed activated sludge. The troubleshooter may encounter any of the variations during his/her technical assistance efforts. Hence, the troubleshooter must be familiar with the design and operating characteristics of each process variation.

Trainee Entry Level Behavior: The trainee should have achieved the learning objectives specified for Unit 11, Lesson 2, before beginning Unit 11, Lesson 3.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. Using references in the *Trainee Notebook*, describe and compare the design and operational characteristics of the major variations of the activated sludge process and explain how a change in operating mode could be used to solve an activated sludge process control problem.
2. Cite examples from his/her experience which illustrate how mode change has been used or could have been used to solve an operational problem.

Instructional Approach: Illustrated lecture with trainee discussion.

Lesson Schedule: The 25 minutes allocated to this Lesson should be scheduled as follows:

TIME	SUBJECT
0 - 2 minutes	Introduce Lesson
2 - 20 minutes	Activated Sludge Process Variations
20 - 25 minutes	Examples of Mode Change In Process Troubleshooting

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, page T11.3.1, "Activated Sludge Process Variations, Design and Operating Parameters."

2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, page 56-57.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 11, Lesson 3, pages 11.3.1 - 11.3.9

2. Slides 179.2/11.3.1 - 179.2/11.3.6.

Instructor Materials Recommended for Development: The instructor should be prepared to cite one or two examples from his/her experience to illustrate the use of activated sludge mode variation as a troubleshooting or operational control tool.

Additional Instructor References:

1. Metcalf and Eddy, Inc., *Wastewater Engineering Treatment Disposal Reuse*, Chapters 9 and 10, McGraw-Hill Book Co., New York, NY (2nd edition, 1979).

2. Stewart, M.J., "Activated Sludge Process Variations. The Complete Spectrum," Article in 3 parts, *Water and Sewage Works, 111(RN)*, pp. R241-R262 (November 30, 1964).

Classroom Set-Up: As specified in Unit 11, Lesson 1, page 11.1.4.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

I. Introduce Lesson (2 minutes)

Use Slide 179.2/11.3.1
Slide 179.2/11.3.1 is a blank

A. Reason for Lesson

1. Many variations to activated sludge process are used

2. Troubleshooters may encounter any of the variations

3. Troubleshooters must be familiar with design and operation of all process variations

B. Lesson Objectives

1. Review design and operational parameters for activated sludge process variations

2. Discuss use of mode change as an operational or troubleshooting tool

3. Cite examples showing use of mode change as a problem solving tool

C. Refer class to

1. *Trainee Notebook*, page T11.3.1 which lists parameters for activated sludge process variations

2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 56-57 which present schmatic diagrams of process variations

II. Activated Sludge Process Variations (18 minutes)

A. Conventional Activated Sludge Process

Use Slide 179.2/11.3.2
Slide 179.2/11.3.2 is a schemati
flow diagram of the conventional
plug flow activated sludge proces

1. Hydraulic and sludge detention times are solely dependent on influent flow rate and return sludge flow rate.

LESSON OUTLINE

Solids can accumulate only in the aeration basin or final clarifier. There is limited sludge storage capability.

2. Hence, a conventional system operating near the upper limits of the loading ranges may not be able to absorb shock loads, organic or hydraulic

3. Similarly, a conventional system which is underloaded may produce over oxidized sludges and nitrified effluents which cause clarification problems.

B. Contact Stablization, Two-Stage Aeration or Sludge Reaeration

1. Differentiate between contact stabilization (30 to 60 min. contact time), two-stage aeration (90 to 180 min. contact time) and conventional system with sludge reaeration (4 to 8 hr. contact time).

2. The reaeration basin permits accumulation of sludge under aeration. This permits some flexibility in control of sludge aeration time, permits accumulation of sludge to increase sludge inventory and reduce F/M, and provides a sludge buffer to prevent total solids washout under temporary severe hydraulic overload conditions (storm water after a storm).

3. Contact time of sludge with wastewater may limit BOD removal. System normally used where influent BOD is colloidal in nature.

4. Note that many processes designed as contact stabilization actually operate as two-stage aeration plants or as

KEY POINTS & INSTRUCTOR GUIDE

Note to Instructor: The flow schematic shows the WAS flow returned to the primary clarifier which is a common design for conventional systems. Better design practice is to avoid wasting to the primary clarifier and waste directly to the solids handling and disposal system because
1. Reduce load on primary clarifier and aeration system
2. Anoxic conditions in primary clarifier promote release of phosphorous which ahs been accumulated by the activated sludge and hence recycle of phosphorous through the system.

Use Slide 179.2/11.3.3
Slide 179.2/11.3.3 is a schematic flow diagram of a contact stabilization process

Comment on problems caused by not having a primary clarifier.

LESSON OUTLINE

conventional plants with sludge reaeration because contact times exceed 60 minutes and stabilization times exceed eight hours. This is caused by flow rates being much less than design flow at newly constructed plants. Such underloaded plants tend to have very old, over-oxidized sludges which produce turbid effluents. Problem solution at such plants may be to convert operation to conventional or extended aeration modes by changing flow patterns.

C. Extended Aeration

1. Characterized by low F/M and stable rapidly settling sludge.
2. Clarifiers are usually designed for relatively low surface loadings (200-400 gpd/ft^2) resulting in fairly good clarification. Return rates are high (100% of influent flow).
3. Usually produce a fully nitrified or partially nitrified effluent. High return rate prevents denitrification in final clarifier.
4. Effluent is usually turbid because of ashing and the poor clarification achieved by rapidly settling sludges.
5. Very good BOD removals (95%+).
6. Resistant to shock loads because of large aeration volume (18-24 hour detention time).

D. Step Feed

1. Use step feed diagram to illustrate how mode change can be used in problem solving.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.3.4

Slide 179.2/11.3.4 is a schematic flow diagram of an extended aeration facility

Comment on problems caused by not having a primary clarifier

Use Slide 179.2/11.3.5

Slide 179.2/11.3.5 is a schematic flow diagram of a step feed activated sludge plant

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Step feed can be varied from conventional to contact mode. Use slide to show how this change is accomplished.	
3. By increasing or decreasing the tank volume used for sludge reaeration the sludge inventory and sludge aeration time can be varied over wide ranges.	
4. Conditions which might indicate mode change (assume that system is being operated in conventional mode before change is affected):	
a. Sudden increase in hydraulic load (storm water run-off) - change to contact mode to protect sludge inventory.	
b. Sludge begins to settle slowly and RR begins to increase - change to sludge reaeration mode to increase sludge inventory and sludge aeration time. Cause sludge to become more stable, settle faster and lower RR.	
c. Troubleshooter may see system as an extreme problem - very slow settling sludge spilling over weirs or severely over-oxidized sludge which has deflocculated and losing excess solids. Mode changes offer quick response to correct these conditions.	
E. Other variations	
1. Complete Mixing	Use Slide 179.2/11.4.5
a. Complete mixing provides some protection against "shock" or "slug" loads.	Slide 179.2/11.4.5 is a schematic diagram of the complete mixing activated sludge process

LESSON OUTLINE

b. Operating parameters

1) F/M: 0.2-0.6 #BOD$_5$/#MLVSS/day

2) Aerator Loading: 50-120 #BOD$_5$/1000 ft^3

3) MLSS: 3000-6000 mg/l

4) Detention Time: 3-5 hours

5) MCRT: 5-15 days

6) Return sludge flow rate: 25-100% of influent

c. Higher loadings tend to produce a slower settling sludge than conventional processes but otherwise the operation is similar.

2. Oxidation Ditch-an extended aeration plant with an "oval doughnut" aeration basin configuration. Brush aerators are used to circulate mixed liquor around the aeration basin. Sometimes called a "Dutch Ditch" or "Race Track".

3. Tapered aeration - a conventional plug flow plant with the air application tapered from the head of the plant (high oxygen demand zone and higher aeration rate) to the effluent end of the tank (low oxygen demand zone and lower aeration rate).

III. Examples of Mode Change for Process Troubleshooting (5 minutes)

A. Ask class to cite examples from their experiences of mode changes used for process control or troubleshooting.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.3.6
Slide 179.2/11.3.6 is a blank

Refer class to *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, page 57.

LESSON OUTLINE

B. Discuss class inputs

C. Instructor should be prepared to cite examples if class does not offer examples.

KEY POINTS & INSTRUCTOR GUIDE

Example of Mode Change for Process Troubleshooting and Operational Control (Example is based on the experiences of the Operational Technology Branch, National Training and Operational Technology Center, U.S. Environmental Protection Agency, Cincinnati Ohio).

1. Plant design is about 2 MGD

2. Plant has two aeration basins which can be operated

   a. In series, plug flow

   b. In parallel

   c. One tank on-line, one tank off-line

   d. One tank as "Contact basin" and one tank as "reaeration basin"

3. Large portion of raw waste comes from a large bakery which discharges a high carbohydrate waste with high grease and oil content.

4. Plant has constant slow settling (bulking) sludge problems when aeration basins are operated in series or in parallel. Solids cannot be retained in the system.

5. By operating with one tank as a contact tank and the other as a reaeration tank, the

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	solids could be retained and stabilized. However, prolonged operation in this mode resulted in over-oxidation of the sludge producing a fast settling sludge which left a turbid effluent which exceeded TSS standards.
	6. Plant personnel were taught to monitor sludge settling characteristics and to switch the plant from the "reaeration operating mode" to an operating mode with the aeration tanks in parallel when sludge settling began to increase. As settling rates became slower, the plant was switched back to the "reaeration" mode.
	7. The plant operated for over a year using mode change to control sludge quality and consistently produced a high quality effluent which exceeded NPDES permit requirements.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 3: Activated Sludge Process Variations

Trainee Notebook Contents

Design and Operating Parameters Chart. T11.3.1

ACTIVATED SLUDGE PROCESS VARIATIONS
DESIGN AND OPERATING PARAMETERS

PARAMETERS	CONVENTIONAL ACT. SLUDGE	STEP AERATION	CONTACT STABILIZATION		TWO-STAGE AERATION		EXTENDED AERATION	FORMULA
			CONTACT	REAERATION	CONTACT	REAERATION		
Aeration Detention Time (Hrs)	4-8	3-8	0.5-1.0	1-4	1.5-3.0	6-9	18-30	$\frac{\text{Aeration Tanks Capacity (gal)}}{\text{Quantity Aeration Tanks Influent flow (gal/hr)}}$
Food to Microorganism Ratio	0.2-0.5	0.2-0.5	0.15-0.2		.07-.15		.01-.07	$\frac{\text{Lbs BOD Applied to Aeration}}{\text{Lbs Solids Under Aeration + Lbs Solids in Clarifier}}$
Aeration Tank Organic Loading	30-40	40-60	30-35		14-30		12.5-14	$\frac{\text{Lbs BOD Influent (Primary or Raw Sewage)}}{\text{Volume of Tanks (1000 ft}^3\text{)}}$
Air Requirement Diffused (ft^3/#BOD)	750-1000	500-700	750-1500		750-1500		2000-2500	$\frac{\text{Air Applied (ft}^3\text{)}}{\text{\# BOD Entering Aeration Tank}}$
Mixed Liquor Suspended Solids (mg/l)	2000	2000	3000	6000	3000	6000	4000	$\frac{\text{mg Dry Solids}}{\text{1 Liter of Mixed Liquor}}$
Return Sludge Concentration (mg/l)	10,000	10,000	6000		6000		8000	$\frac{\text{mg Dry Solids}}{\text{1 Liter of Return Sludge}}$
Return Sludge (% of influent)	15-75	20-75	50-150		50-150		50-200	$\frac{\text{Rate Sludge Return (gal)}}{\text{Primary or Raw Sewage Rate (gal)}} \times 100$
MCRT - Sludge Age (days)	4-8	4-8	8-10		10-15		10-30	$\frac{\text{Lbs of Suspended Solids in System}}{\text{Lbs of Suspended Solid Wasted/Day + Lbs Effluent Suspended Solid/Day}}$
Sludge Volume Index (SVI)	50-150	50-150	50-150		50-150		25-110	$\frac{\text{30 min Settling Results (mg/l)} \times 1000}{\text{MLSS (mg/l)}}$
Solids Accumulation Rate (#solids/#BOD removed)	0.4-0.6	0.4-0.6	0.2-0.4		0.15-0.20		0.12-0.14	$\frac{\text{Lbs Solids Accumulated in System}}{\text{Lbs BOD Removed}}$
Clarifier Overflow Rate (g/ft^2/day)	800-1000	800-1000	400-800		400-800		300-600	$\frac{\text{Mixed Liquor Applied to Clarifier (gal/day)}}{\text{Surface Area Clarifier (ft}^2\text{)}}$
Clarifier Detention Time (hrs)	1-3	1-3	2-3		2-3		2-3	$\frac{\text{Capacity of Clarifier (gal)}}{\text{Quantity of Flow Raw Sewage or Primary Effluent (gal/hr)}}$
Clarifier Weir Over Flow Rate (g/ft/day)	10,000	10,000	10,000		10,000		10,000	$\frac{\text{Flow to Clarifier (gal/day)}}{\text{Length of Effluent Weirs (ft)}}$
% BOD Remaining	6	5	2		1		0.5	$\frac{\text{Effluent BOD}}{\text{Influent BOD}} \times 100$
Respiration Rate (mg O_2/hr/g)	12-20	8-20	20-30	10-20	15-20	5-8	3-5	O.U.R. (mg O_2/min) $\times \frac{\text{60 min}}{\text{1 hr}} \times \frac{1}{\text{MLVSS (gms)}}$

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 4: Microscopic Evaluation of Sludge

Lesson 4 of 14 lessons Recommended Time : 25 minutes

Purpose: The predominant species of organisms in activated sludge are indicators of process condition and sludge quality. Periodic microscopic examination of the activated sludge to identify changes in the relative numbers of each species in the sludge population can be used as a guide in process control decision making. This lesson reviews microscopic techniques for examining activated sludge and applies the microscopic observations to process evaluation.

Trainee Entry Level Behavior: The trainee should have achieved the learning objectives in Unit 11, Lesson 3 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. From memory, explain how the microscope is used to evaluate activated sludge quality.
2. From memory, describe the microscopic examination procedures for activated sludge.
3. From memory, list and describe the principal microorganisms found in activated sludge.
4. From memory, list the types and relative predominance of microorganisms that are characteristic of good and bad conditions in activated sludge systems.

Instructional Approach: Illustrated lecture with class discussion. Optional Approach: Trainee performance of microscopic examination procedures for activated sludge.

Lesson Schedule: The 25 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 10 minutes	Microorganisms in Activated Sludge
10 - 20 minutes	Indicators of Process Condition
20 - 25 minutes	Microscopic Techniques

If the optional demonstration of laboratory microscopic examination procedures is used, add 25 minutes to the lesson.

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, page T11.4.1, "Relative Number of Microorganisms vs. Sludge Quality."
2. *Trainee Notebook*, page T11.4.2, "Worksheet for Microscopic Examination of Activated Sludge."
3. *Operators Pocket Guide to Activated Sludge, Part I-The Basics*, pages 7-9.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 11.4.1 - 11.4.11
2. Slides 179.2/11.4.1 - 179.2/11.4.22.
3. Optional Materials (to be provided by Instructor, if used)
    a. Projecting microscope or at least three (3) biocular laboratory microscopes
    b. Microscope accessories such as slides, cover slips, pipets, wash bottles, lens paper and sample bottles
    c. Three activated sludge samples
        1) Sample of young sludge
        2) Sample of normal or good quality sludge
        3) Sample of old sludge

Instructor Materials Recommended for Development: Instructor may wish to supplement the photomicrographs provided in the lesson with photomicrographs from the instructor's collection. The sequence on use of the microscope may be supplemented with procedures for using the microscopes available to the class if the instructor chooses to have the class perform the microscopic examination procedures

Additional Instructor References:

1. Jahn, T.C., *How to Know the Protozoa*, William C. Brown Publishers (1976).

2. Prescott, G. W., *How to Know Freshwater Algae*, William C. Brown Publishers (1970).

3. *Standard Methods for the Examination of Water and Wastewater*, A.P.H.A., A.W.W.A. and W.P.C.F. (14th edition, 1975).

4. *Process Control Manual for Aerobic Biological Treatment Facilities*, EPA-430/9-77-006, pp. IV 18-26, U.S. Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (March, 1977).

Classroom Set-Up: As specified in Unit 11, Lesson 1.
Optional classroom set-up: Laboratory set-up and equipment for microscopic evaluation of activated sludge or microscopic viewing stations set-up in the classroom so that the viewing stations do not interfere with the lecture/discussion segment of the lesson.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Types of Microorganisms in Activated Sludge (10 minutes)	Use Slide 179.2/11.4.1 Slide 179.2/11.4.1 is a blank
A. As discussed earlier, activated sludge performance is related to the purifying activity of the microorganisms that make up its zoogleal mass. The presence of various microorganims can quickly indicate good or poor sludge quality and system performance. Regular examination of the various types of microorganisms can signal upcoming changes in sludge quality and the performance of activated sludge treatment plants before many of the more traditional process control tests do so.	
B. List organisms typically found in activated sludge	Use Slide 179.2/11.4.2 Slide 179.2/11.4.2 is a word slide which reads:
1. Use Slide 179.2/11.4.2 to list organisms normally found in activated sludge	"Microorganisms in Activated Sludge
2. Each will be discussed in more detail, illustrated and its significance in process evaluation discussed	Bacteria Amoeboids Flagellates Ciliates Free Swimming Ciliates Stalked Ciliates Rotifers and other 'Small Animals' Filaments Worms"
C. Bacteria	Use Slide 179.2/11.4.3 Slide 179.2/11.4.3 is a photomicrograph showing an activated sludge particle at low magnification (100x)
1. Bacteria are most predominant species in activated sludge. Their numbers approach Scrooge McDuck's "Fantabulous Octillion" (see Walt Disney comics)"	
2. The aerobic and facultative bacteria are the activated sludge workers who	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
remove and stabilize the waste	
a. Aerobic - must have free oxygen for growth	
b. Facultative - use aerobic metabolism when free oxygen is available but can also function and grow in the absence of free oxygen	
3. Many bacterial species are present but the bacteria are very small. Under magnification normally used to examine activated sludge (70x to 400x) the individual bacterial cells cannot be differentiated. Thus, the bacteria will appear as the floc particle illustrated in Slide 179.2/11.4.3. The floc particle contains many millions of bacteria.	
D. Amoeboids	Use Slide 179.2/11.4.4 Slide 179.2/11.4.4 is a photomicrograph of an amoeba. The amoeba is stained to provide color contrast. In natural state would be light, almost translucent, grey very similar to the background color
1. "Glob-like" microorganisms - move slowly	
2. Move by pseudopodia - eat by engulfing food - eat bacteria	
3. Predominate in MLSS during plant start-ups and recovery from an upset condition	
E. Flagellates	Use Slide 179.2/11/4.5 Slide 179.2/11.4.5 is a photomicrograph of a low MLSS activated sludge. A "flagellate" is visible in the left center of the photo
1. Characterized by a tail (flagella) that extends from their round bodies	
2. They move quickly - darting in a corkscrew motion from the whipping of the tail	
3. They predominate in MLSS when there is	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
a high organic load (high BOD), low population of bacteria and light, dispersed floc	
4. As a more dense floc develops, the flagellates will lose their predominance as the bacteria increase. In older, denser populations, there are few flagellates	
F. Ciliates	Use Slide 179.2/11.4.6 Slide 179.2/11.4.6 is a blank
1. Ciliates are more "mature" microorganisms that are responsible for clarification of the MLSS	
2. They have rotating hair-like cilia that cover all or part of their bodies	
3. Their motion is slow to medium with a sort of flowing motion that is created by the movement of their cilia	
4. There are two types of ciliates:	
a. Free-Swimming Ciliates	Use Slide 179.2/11.4.7 Slide 179.2/11.4.7 is a photomicrograph of "free swimming ciliate"
1) Occur when there is a large number of bacteria in the MLSS	
2) Feed on bacteria in a "grazing" motion	
3) Their presence occurs during fair to good settling conditions	
b. Stalked Ciliates	Use Slide 179.2/11.4.8 Slide 179.2/11.4.8 is a photomicrograph showing a stalked ciliate
1) "Mature" ciliates	
2) Occur after the free swimmers are no longer able to compete for the available food	

LESSON OUTLINE

3) They often occur with rotifers - an indication of good settling conditions

G. Rotifers

1. These are not protozoans - they are "metazoans" (small animals)
2. They are very large and move with a steady motion
3. They have a tendency to eat everything in sight, so don't be surprised to see them devour almost everything under your prepared slide
4. They signal a stable activated sludge population - one with good settling conditions
5. If there are too many rotifers, this could indicate a very old, highly oxidized sludge

H. Filaments

1. These are non-moving string-like organisms
2. They are bacteria and/or fungi (it's often difficult to tell them apart)
3. Small filaments are necessary to hold the activated sludge floc together. An overabundance of the filaments creates a "net-like effect" that results in poor settling
4. They often occur due to low nutrients, low D.O. (fringe conditions)

I. Worms

1. Their significance varies from plant to plant

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.4.9
Slide 179.2/11.4.9 is a photomicrograph showing a rotifer

Use Slide 179.2/11.4.10
Slide 179.2/11.4.10 is a photomicrograph showing filamentous organisms

Use Slide 179.2/11.4.11
Slide 179.2/11.4.11 is a blank

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2) Often they are seasonal and do not create problems unless they become too abundant	
3. They may be insect larvae, nematodes, large protozoan, etc.	
4. Ask class if they have had experience with occurance of worms at treatment plants	
II. Significance of Microscopic Examination in Indicating Process Condition (10 minutes)	Use Slide 179.2/11.4.12 Slide 179.2/11.4.12 is a word slide which reads:
A. Detail the significance of the different types of microorganisms that occur during satisfactory and good sludge conditions by discussing information on Slide 179.2/11.4.12	"Significance of Microorganisms in Activated Sludge Sludge Condition Satisfactory Sludge Bacteria Flocculate Acceptable Settleability Protozoan Population Large Number of Free Swimming Ciliates Some Stalked Ciliates Few Flagellates or Amoeboids Good Sludge Good Settleability Effluent BOD_5 Low Protozoan Population Large Number of Stalked Ciliates Some Free Swimming Ciliates Few Rotifers Very Few Flagellates"
B. Detail the types of microorganisms that occur during unsatisfactory and bad sludge conditions by discussing the information on Slide 179.2/11.4.13	Use Slide 179.2/11.4.13 Slide 179.2/11.4.13 is a word slid which reads: "Significance of Microorganisms in Activated Sludge Sludge Condition Bad Sludge Bacterial Dispersal No Flocculation

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	Protozoan Population Large numbers of 1. Flagellates 2. Amoeboids Relatively Few Ciliates Unsatisfactory Sludge Bacterial Dispersal Some Flocculation
	Protozoan Population Present: 1. Flagellates 2. Amoeboids Some Ciliates 1. Free Swimming 2. Stalked"
C. Illustrate the relative predominance of the different types of microorganisms	Use Slide 179.2/11.4.14 Slide 179.2/11.4.14 is identical to page T11.4.1 in the *Trainee Notebook.* Refer class to page T11.4.1 in the *Trainee Notebook*
III. Microscope Technique for Troubleshooting Activated Sludge Systems (5 minutes)	
A. Obtain representative sample of MLSS (follow sampling considerations)	Use Slide 179.2/11.4.15 Slide 179.2/11.4.15 is a photograph showing sample collection at the aeration basin
B. Use appropriate microscope 1. Built-in light 2. 10X and 40X objectives 3. Condenser system 4. 10X eyepiece 5. Movable stage	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
C. Clean cover slip, slides	Use Slide 179.2/11.4.16 Slide 179.2/11.4.16 is a photograph showing technician cleaning microscope slide and coverslip
D. Use clean pipet to pick up sample of mixed sludge	Use Slide 179.2/11.4.17 Slide 179.2/11.417 is a photograph showing technician pipeting an activated sludge sample
E. Place one drop of sludge from pipet onto middle of microscope slide - lift finger momentarily from pipet to do this	Use Slide 179.2/11.4.18 Slide 179.2/11.4.18 is a photograph showing technician placing drop of sample on the microscope slide
F. Pick up cover slip by 2 corners and slip it along slide until it touches the drop	Use Slide 179.2/11.4.19 Slide 179.2/11.4.19 is a photograph showing proper technique to placing coverslips on microscope slides
G. Allow cover slip to fall onto glass slide	
H. Place microscopic slide onto microscope stage and examine slide	Use Slide 179.2/11.4.20 Slide 179.2/11.4.20 is a photograph showing proper placement of slide on the microscope stage
I. Procedures for Examination 1. Record date, time and other important plant performance data	Use Slide 179.2/11.4.21 Slide 179.2/11.4.21 is a photograph of page T11.4.2 in the *Trainee Notebook*
2. Examine 3 slides per sample	Refer class to page T11.4.2 in the *Trainee Notebook*
3. Scan each slide side-to-side, top-to-bottom (use standard technique each time you examine the slides)	
4. Provide a mark on the Worksheet each time you see a member of a Microorganism Group	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
5. Count the total number of microorganisms within each group	Guide: Use worksheet to tally numbers
6. Determine the Predominating Organisms	
IV. Questions	Use Slide 179.2/11.4.22 Slide 179.11.4.22 is a blank
A. Respond to questions from class	
B. Proceed to Optional Demonstration/Practice if it is used in the lesson	
V. Lab Demonstration - Microscopic Examination (25 minutes)	This is an optional activity in Lesson 4. If used add 25 minutes to lesson time.
A. Use fresh activated sludge sample to perform each step in the microscopic examination of activated sludge	The following equipment and supplies are needed:
B. Place prepared slide on stage of projecting microscope	1. Projecting microscope or three (3) biocular laboratory microscopes
C. Have class surround projection screen and examine the culture as a group	2. Three activated sludge samples
Pay particular attention to relative sizes, and systems of movement as indications of organism types	a. Young sludge b. Normal sludge c. Old sludge
D. Respond to class questions and encourage discussion	3. Microscope accessories
	Instructor may prepare slides as demonstration or may have trainees prepare slides as a practicum

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

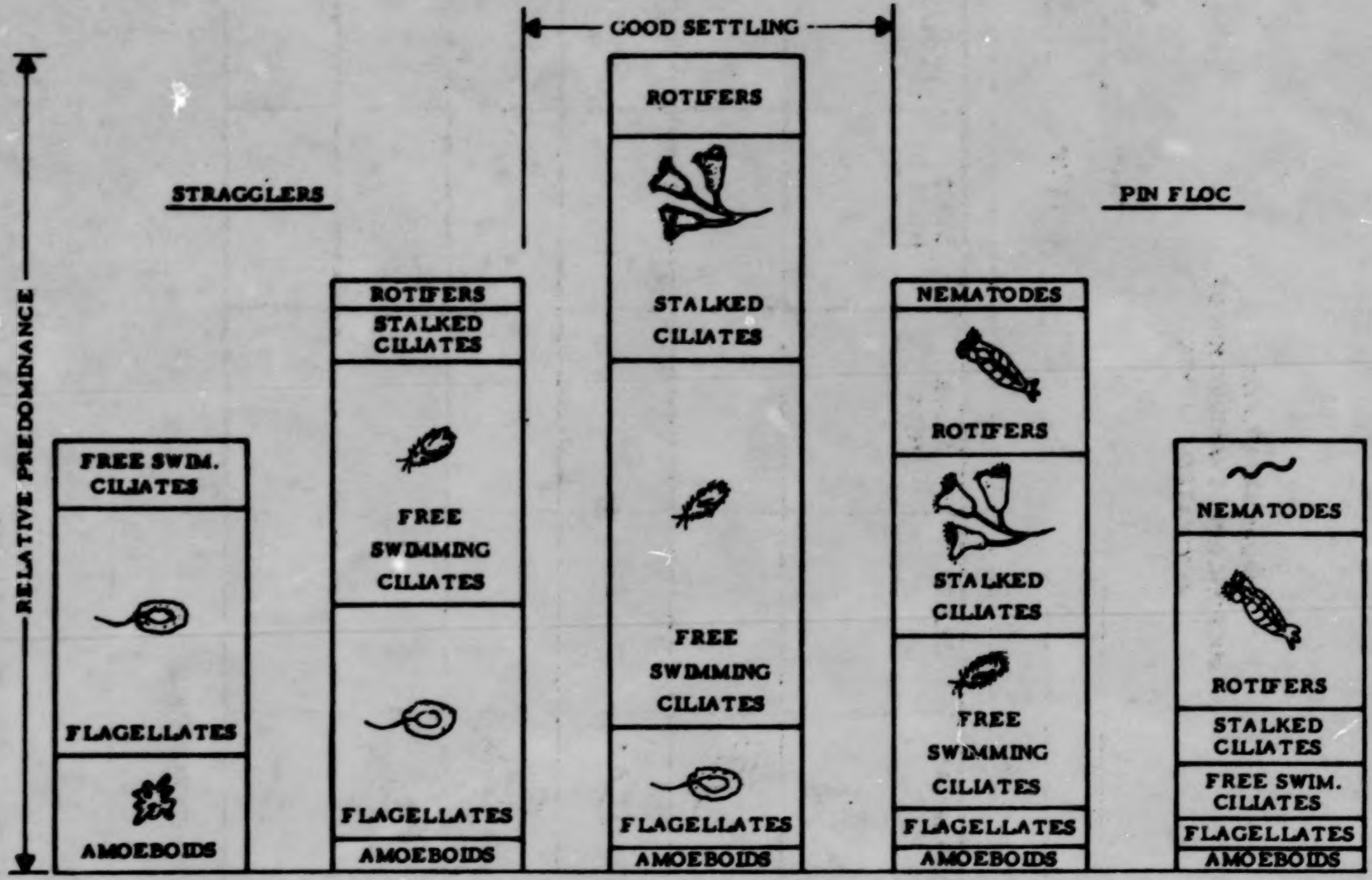
Lesson 4: Microscopic Evaluation of Sludge

Trainee Notebook Contents

Relative Number of Microorganisms vs. Sludge Quality T11.4.1

Worksheet for Microscopic Examination of Activated Sludge T11.4.2

T11.4.1



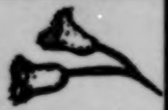
RELATIVE NUMBER OF MICROORGANISMS VS. SLUDGE QUALITY

WORKSHEET FOR MICROSCOPIC EXAMINATION OF ACTIVATED SLUDGE

DATE: ______________________ TIME: ________ AM PM

BY: ______________________ TEMP: ________ °C

SAMPLE LOCATION: ____

MICROORGANISM GROUP	SLIDE NO. 1	SLIDE NO. 2	SLIDE NO. 3	TOTAL
AMOEBOIDS				
FLAGELLATES				
FREE SWIMMING CILIATES				
STALKED CILIATES 				
ROTIFERS				
WORMS				

RELATIVE PREDOMINANCE:

1. ______________________________
2. ______________________________
3. ______________________________

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 5: Process Control Based on Sludge Settleability

Lesson 5 of 14 lessons Recommended Time: 50 minutes

Purpose: Activated sludge process treatment depends on producing sludge solids which can be separated from the liquid phase in the final clarifier. The settling characteristics of the mixed liquor suspended solids vary with conditions in the aeration basin and final clarifier. Observation of sludge settling characteristics provides valuable information for determining process adjustments to maintain or improve sludge quality. This lesson describes sludge settling test procedures and discusses the application of settling test data to process control.

Trainee Entry Level Behavior: Trainees should have achieved the learning objectives specified for lessons 1-4 of Unit 11 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. From memory, list the equipment and samples used in the evaluation of sludge settling characteristics, describe the test procedures, and list the observations and data to be recorded.
2. From memory, describe how sludge settleability is used in process control.
3. From memory, describe the effects of return sludge flow rate, waste sludge rate and aeration detention time on sludge settleability.
4. From memory, describe the relationship between sludge settleability and the other process control parameters, F/M, MCRT and respiration rate (RR).

Instructional Approach: Illustrated lecture with class discussion.

Lesson Schedule: Within the 50 minutes allocated to this lesson, the following schedule should be followed:

TIME	SUBJECT
0 - 5 minutes	Introduction
5 - 10 minutes	Samples for Sludge Settleability
10 - 15 minutes	Sludge Blanket Determination
15 - 20 minutes	Centrifuge Test for Solids Concentrations
20 - 30 minutes	Sludge Settling Test Procedures
30 - 45 minutes	Interpretation of Settling Test Data
45 - 50 minutes	Discussion

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T11.5.1- T11.5.8 , "Activated Sludge Process Data for Use with West's Sludge Quality Control Procedures"

2. West, A.W., *Operational Control Procedures for the Activated Sludge Process, Parts I, II, Appendix and Updated Summary,* U. S. Environmental Protection Agency, National Training and Operational Technology Center, Cincinnati, Ohio.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 11.5.1 - 11.5.27, Unit 11, Lesson 5.

2. Slides 179.2/11.5.1 - 179.2/11.5.29.

Instructor Materials Recommended for Development: Example problems for practicing sludge settleability calculations may be developed for use with class who require such practice

Additional Instructor References: Same as Unit 11, Lesson 1.

Classroom Set-Up: As specified in Unit 11, Lesson 1.

LESSON OUTLINE

I. Introduction (5 minutes)

A. Review activated sludge process objectives to produce settleable solids which can be separated from the treated wastewater in the final clarifier and concentrated for recycle or disposal

B. Reiterate the characteristics of good sludge quality

1. Settles fairly rapidly as contrasted to a sludge that settles very fast or very slowly

2. Concentrates uniformly in 30-60 minutes as contrasted to a sludge that concentrates very rapidly in less than 30 minutes or very slowly needing 2 hours or longer to concentrate

3. Produces flocculent solids which form large, strong floc particles which settle well, resist shear in the aeration basin and final clarifier and filter the supernate to remove stray particles as contrasted to a sludge which does not flocculate to produce settleable floc particles or produces a weak floc which shears easily or is granular and does not filter the effluent or produces excessive large light floc particles which do not settle

4. Produces a clear supernate as contrasted to a sludge which leaves a turbid supernate or a sludge which produces straggler floc, pin floc or ash

5. Good sludge normally is deep tan to light brown in color while poor

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.5.1
Slide 179.2/11.5.1 is a blank

Instructor should be thoroughly familiar with West's pamphlet series *Operational Control Procedures for the Activated Sludge Process, Parts I, II, Appendix and Updated Summary*

LESSON OUTLINE

sludges are very light in color (young sludges) or very dark brown (old sludges) or black (septic sludges)

6. Good activated sludge normally has a pleasant musty earth odor but bad sludges may have unpleasant odors

C. Observation of sludge settling characteristics in a laboratory settling test and the settling and concentration characteristics in the final clarifier are probably the best ways to measure sludge quality

D. Settling observations will be used to determine changes in return sludge rate or waste sludge rate to maintain or improve sludge quality

II. Samples for Sludge Settleability Determination (5 minutes)

A. Use Slide 179.2/11.5.2 and point out sampling locations and sample volumes needed to perform sludge settleability test and control procedures

B. Visual Observations

1. Aeration Tank

a. Foam

1) Color

2) Quantity

3) Type

b. Mixing adequacy

c. Sludge color and odor

d. Adequate D.O.

KEY POINTS &
INSTRUCTOR GUIDE

Use Slide 179.2/11.5.2

Slide 179.2/11.5.2 is a schematic diagram of an activated sludge plant showing the aeration basin and final clarifier in cross-section

LESSON OUTLINE

KEY POINTS &
INSTRUCTOR GUIDE

2. Final Clarifier
    a. Surface appearance
        1) Scum
        2) Ashing
        3) Clumping
        4) Floating sludge
    b. Sludge blanket depth
        1) Distance from liquid surface to top of blanket is sludge blanket depth
        2) Distance from top of blanket to bottom of the clarifier is sludge blanket thickness

Measurement procedures for sludge blanket depth will be discussed in Section III of this lesson

    c. Billowing (hydraulic effects)
    d. Bulking
    e. Clarity of effluent
    f. Adequacy of mechanical functioning of clarifier components
3. The significance of visual observations will be discussed in Unit 11, Lesson 8

C. Flow Rate Measurements
1. Influent Flow
2. Return Sludge Flow
3. Waste Activated Sludge Flow
4. Clarifier Effluent Flow

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

D. Samples for Settling Test

  1. Mixed liquor as it enters the final clarifier or as it leaves the aeration basin

  2. Need about 3 liters of mixed liquor

  3. Should be taken to laboratory for settling test immediately

E. Samples for Solids Determination

  1. Return sludge - 500 ml

  2. Waste activated sludge - 500 ml

  3. Mixed liquor - taken from sample collected for settling tests - 500 ml

  4. Reaeration basin mixed liquor - 500 ml (only if sludge reaeration is practiced)

F. Final Clarifier Overflow

  1. 500 ml from clearest part of clarifier surface

  2. Determine final clarifier effluent turbidity as measure of clarifier efficiency and to monitor solids in final effluent

III. Sludge Blanket Depth Measurement (5 minutes)

A. Sludge Blanket Finder

  1. 1½" aluminum pipe - 12 - 16' long depending on final clarifier depth

  2. Fitted with sight glass (water tight seal)

  3. Water proof light source below sight glass

Use Slide 179.2/11.5.3
Slide 179.2/11.5.3 is a photograph showing sight glass and lamp assembly for sludge blanket finder

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
4. Linear scale along pipe shaft	
5. Above is "home-made" sludge blanket finder. Numerous commerical blanket finders such as	
a. Sonic	
b. Electronic	
c. Photo-electric	
d. Sludge Judge (coring-type blanket finder)	
e. Thief tubes along clarifier depth	
B. Measurement Procedure	
1. Insert blanket finder into clarifier	Use Slide 179.2/11.5.4 Slide 179.2/11.5.4 is a slide showing operator inserting blanket finder into final clarifier
a. Measure at point which represents average blanket depth	
b. Circular clarifier - 1/3 radial distance from outer walls or 2/3 radial distance from center of clarifier	
c. Rectangular clarifier - 2/3 clarifier length from clarifier influent end	
2. Slowly lower blanket finder into clarifier while looking down pipe shaft to detect top of blanket as the light source passes into the blanket but before sight glass enters the blanket	Use Slide 179.2/11.5.5 Slide 179.2/11.5.5 is a photograph showing the operator observing the liquid-sludge blanket interface through the blanket finder
3. Tips on blanket detection	
a. Point out zones in clarifer	Use Slide 179.2/11.5.6 Slide 179.2/11.5.6 is a schematic of the final clarifier cross-
1. Compression zone near bottom	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
of clarifier. Solids concentration about equal RSC	section showing the sludge blanket thickness. Schematic shows the compression zone, the hindered settling zone, clarification zone and clarified liquid
2) Hindered settling zone above compression zone - solids concentration about equal to MLSS	
3) Clarification zone where discrete floc particles can be observed	
4) Clarified liquid above the clarification zone	
5) Sludge blanket thickness is the hindered settling zone plus the compression zone	
6) Sludge blanket depth is the distance from the liquid surface to the top of the hindered settling zone	
b. Move blanket finder slowly through the clarification zone. Observe discrete floc particles and note any unusual appearances	Use Slide 179.2/11.5.7 Slide 179.2/11.5.7 is a schematic of the final clarifier cross-section showing the blanket finder moving through the clarification zone
c. Care must be taken not to measure the blanket depth at some point in the hindered settling zone. In this zone the light is totally obscured	Use Slide 179.2/11.5.8 Slide 179.2/11.5.8 is a schematic of the final clarifier cross-section showing the blanket finder moving into the hindered settling zone
d. Measure the blanket depth as the interface between the clarification zone and the hindered settling zone and record this reading as the sludge blanket depth	Use Slide 179.2/11.5.9 Slide 179.2/11.5.9 is a schematic of the final clarifier cross-section showing the blanket finder at the interface between the clarification and hindered settling zones

LESSON OUTLINE

C. Significance of Sludge Blanket Depth

1. Locates blanket in final clarifier
    a. Warns of potential wash-out problems (high blanket)
    b. Identifies inadequate concentration time (very low or no sludge blanket)
        1) Return rate too high and returning diluted sludge
        2) Wasting too much causing dilute return sludge and potential problem with excessive reduction in solids inventory
    c. Blanket should be in bottom third of clarifier
2. Used to calculate final clarifier solids inventory. Refer to Unit 11, Lesson 2
3. Sludge blanket control
    a. Some operators use blanket depth to control return sludge rates
        1) Rising blanket - increase return
        2) Falling blanket - decrease return
        3) Limitations
            a) Does not consider sludge quality changes or total system solids inventory requirements
            b) May cause process control

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.5.10

Slide 179.2/11.5.10 is a blank

LESSON OUTLINE | KEY POINTS & INSTRUCTOR GUIDE

responses which aggravate rather than solve problems

b. Some operators use blanket depth to control wasting

   1) Rising blanket - increase wasting

   2) Falling blanket - decrease wasting

   3) Limitations same as listed in III.C.3.a.(3)

c. Process control based on sludge blanket depth is not recommended because

   1) Changes in return and waste rates cause changes in sludge quality which may aggravate high blanket problems

   2) Blanket depth fluctuates with applied hydraulic load to aeration basin

   3) Controls one symptom of problem without considering the cause of the problem

   4) Relief is only temporary when blanket control is by RAS changes (See Unit 11, Lesson 2)

d. Direct control response to sludge blanket depth is justified only when

   1) Blanket is very high and solids wash-out is imminent

   2) Then may increase return or wasting temporarily to lower blanket to prevent wash-out

909

3) When blanket has been lowered and danger of solids wash-out is passed, reduce return and wasting to correct the cause of the problem

IV. Centrifuge Test for Solids Determination (5 minutes)

A. Purposes

1. Used to provide a quick method of approximating the SS concentrations of the mixed liquor, return sludge and waste sludge. Simplicity of test permits frequent determinations

2. Can be used to calculate a mass balance and to develop graphs for control and monitoring of return rates, wasting rates, detention times and solids distribution

3. Must check centrifuge values against gravimetric solids determination daily

B. Test Procedures

1. Collect representative samples

Use Slide 179.2/11.5.11

Slide 179.2/11.5.11 is a photograph of an operator collecting a mixed liquor sample

a. Mixed liquor (same sample may be used for settling test). If multiple tanks are used, sample each separately

b. Return activated sludge

c. Waste activated sludge

2. Mix each sample well and fill centrifuge tubes to full mark (Note API, 12.5 ml tubes with % solids graduations should be used)

3. Place filled tubes in centrifuge

Use Slide 179.2/11.5.12

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
a. Run all samples at same time	Slide 179.2/11.5.12 is a photograph showing technician placing samples in the centrifuge
b. Record sample and centrifuge tube numbers	
c. Note that IEC clinical centrifuge is used but other centrifuges are acceptable	
4. Spin samples for 15 minutes at maximum speed. Note: Time and speed may be changed based on plant experience. Key: always use same speed and same time in a consistent standardized test procedure	Use Slide 179.2/11.5.13 Slide 179.2/11.5.13 is a photograph of the centrifuge and laboratory timer set for 15 minutes
5. Remove one tube at a time and read the amount of suspended matter concentrated in the bottom of the tube. Record results as % solids ATC = aeration tank concentration RSC = return sludge concentration XSC = waste activated sludge concentration	Use Slide 179.2/11.5.14 Slide 179.2/11.5.14 is a photograph of the centrifuge tube after 15 minute spin showing solids deposition
C. Test Precautions 1. Since the test measures % by volume, the test results often vary due to changing sludge settling and compaction characteristics. The sludge settling characteristics must be considered when using the reuslts of the centrifuge test	Use Slide 179.2/11.5.15 Slide 179.2/11.5.15 is a blank
2. Suspended matter correlation	
a. Must perform one suspended solids gravimetrically each day	
b. Define the spin ratio $\text{Spin ratio} = \frac{\text{Suspended Solids, mg/l}}{\text{\% Solids by Centrifuge}}$	Write definition of spin ratio on chalkboard
c. Multiply the % solids by the spin ratio to estimate suspended solids in mg/l	

LESSON OUTLINE

D. Applications

1. Monitor suspended solids concentrations quickly and easily

2. Calculate solids inventory in sludge units

   a. Sludge unit = 1 million gallons x 1% solids by centrifuge

   b. Sludge units = volume (million gallons) x % solids by centrifuge

3. Calculate MCRT in terms of sludge units and hence calculate wasting rates to maintain solids inventory

4. Determine solids imbalances in the system quickly

5. Used with settling test results in calculations to estimate return sludge flows

V. Sludge Settling Test Procedures (10 minutes)

A. Purpose of Settling Test

1. Simulate what happens in final clarifier in a laboratory environment

2. Observe settling, concentration and clarification characteristics of the mixed liquor solids to

   a. Determine sludge quality

   b. Determine changes in sludge quality

   c. Determine process control changes necessary to maintain or to improve sludge quality

KEY POINTS & INSTRUCTOR GUIDE

Refer class to Unit 11, Lesson 2, *Trainee Notebook* materials for sludge unit definition and formula

Write sludge unit definition on chalkboard

LESSON OUTLINE

KEY POINTS &
INSTRUCTOR GUIDE

3. Sludge quality (settling and concentration characteristics) changes as system conditions change - sludge quality (settling and concentration characteristics) are not constant although many persons ignore sludge quality changes as a significant factor in process control decision making or relegate sludge quality considerations to a secondary value in process control

4. Sludge quality (settling and concentration characteristics) respond quickly to changes in process conditions. Thus, sludge quality is a sensitive indicator of process conditions and a valuable process control tool

B. Samples for Settling Tests

1. Settling tests are run on the aeration basin effluent mixed liquor which enters the final clarifier

Use Slide 179.2/11.5.16
Slide 179.2/11.5.16 is a photograph showing an operator collecting an aeration basin mixed liquor sample

2. About 3 liters of sample are needed for the settling test

3. Samples for settling test should be collected last. The settling test must be run as quickly after the sample is collected as possible to have a sample that is representative of the final clarifier influent as possible. Biological activity continues, therefore delays in running the settling test can result in changes in sludge quality

C. Settleometer Test

Use Slide 179.2/11.5.17
Slide 179.2/11.5.17 is a photograph of settleometer, timer and mixed liquor sample

1. This is a measure of sludge settling that is performed in a settleometer, a large diameter settling container, said to better represent the settling environment of a clarifier

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
a. Describe settleometer	
1) 5" diameter	
2) 2 liter capacity	
3) Linear gradations from 0 to 1000	
b. Describe timer - record settling every 5 minutes for first 30 minutes and every 10 minutes from 30 minutes to 60 minutes	Note: Settling test must be extended to 2 - 4 hours for slow settling sludges.
c. Describe mixed liquor sample	
1) Fresh	
2) Representative	
3) Need about 3 liters	
2. Test Procedure	
a. Mix sample thoroughly in sample container and pour sample into settleometer	Use Slide 179.2/11.5.18 Slide 179.2/11.5.18 shows a technician pouring sample into settleometer
b. Stir gently with broad paddle to avoid shearing floc. Dampen liquid movement with paddle before removing	Use Slide 179.2/11.5.19 Slide 179.2/11.5.19 shows technician stirring settleometer contents
c. Begin settling test	Use Slide 179.2/11.5.20 Slide 179.2/11.5.20 shows settleometer at settling time equal to zero
1) Record Settled Sludge Volume (SSV) at time zero as 1000	
2) Observe supernate and sludge blanket surface as it forms. Note observations on data sheet	Refer to *Trainee Notebook*, page T11.5.4 for sample data sheet
a) Fast settling sludge - immediate separation	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b) Turbid supernate	
c) Considerable quantity of solids left at surface	
d) Blanket interface somewhat diffuse	
d. Continue test recording for SSV every five minutes for first 30 minutes. Note:	Use Slide 179.2/11.5.21 through Slide 179.2/11.5.25 Slides show settleometer after 5, 10, 15, 20 and 30 minutes settling respectively
1) Very fast settling	
2) Turbid supernate	
3) Ash on surface	
e. Continue test for at least 60 minutes recording SSV at 30, 40, 50 and 60 minutes	Use Slide 179.2/11.5.26 Slide 179.2/11.5.26 shows settleometer after 40 minutes
1) Note that settling complete after only 20 minutes settling time	
2) Turbid supernate	
c) Ash on surface	
3. Calculations and Graphs	Use Slide 179.2/11.5.27 Slide 179.2/11.5.27 is a graph of SSV vs. time for slow, normal and fast settling sludges
a. SSV = settled sludge volume, mg/l	
1) Results are graphed to show sludge settling characteristics	
2) Discuss slow settling, fast settling and normal settling SSV graphs	
b. The SSC must be calculated to define sludge quality and to determine recycle rates in the activated	Use Slide 179.2/11.5.28 Slide 179.2/11.5.28 is a graph of SSC vs. time for slow, normal and

LESSON OUTLINE

sludge system and sludge wasting requirements

1) $SSC_t = \frac{ATC \times 1000}{SSV_t}$

2) SSC values are graphed and interpreted

3) Discuss SSC curves for slow settling sludges, fast settling sludges and normal settling sludges

VI. Interpretation of Settling Test Data (15 minutes)

A. Clarifier Sludge Flow Control

1. Process control is used to reflect a mass balance around the clarifier. The operator determines the Clarifier Sludge Flow Demand and then determines whether existing clarifier sludge flows are too small or too large. Corrections are then made in return rates to match the desired clarifier sludge flow demand. Sludge quality responses to changes in RSF are fast, about 1/2 aeration detention time.

2. Discuss estimating Clarifier Sludge Flow Demand (CSFD)

a. Normal sludge - adjust clarifier sludge flow to balance RSC with a desired RSC which lies on the "knee" of the SSC vs. time curve. Usually the 40-60 minute SSC value

1) If RSC is greater than desired RSC, then increase return sludge flow rate

KEY POINTS & INSTRUCTOR GUIDE

fast settling sludges. The formula for converting SSV to SSC is shown on the slide

Refer class to West, *Updated Summary of Operational Control Procedures for the Activated Sludge Process*, pp. 7-12

Continue to use Slide 179.2/11.5.28

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2) If RSC is less than the desired RSC, then decrease return sludge flow rate	
3) Rationale - increase or decrease sludge detention time in the clarifier to allow more or less time for the sludge to concentrate	
4) Effect of return sludge control on sludge quality:	Note: Discussion assumes a steady state condition in the final clarifier
a) With a normal sludge, increasing RSF will usually cause the sludge to settle more slowly, i.e., the sludge becomes less stable because the aeration deten- time is decreased.	Effect of an RSF change can be observed in a time frame corresponding to the aeration basin detention time
b) With a normal sludge, decreasing RSF will usually cause the sludge to settle more rapidly, i.e., the sludge becomes more stable because the aeration detention time is increased	
c) With a normal sludge, sludge quality (settleability) is very sensitive to changes in return rate. Therefore, frequent (once or twice per operating shift) measurement of sludge settling and adjustment of return rate is required to maintain process balance and good effluent quality. Such sludges produce very high quality effluents	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

b. Slow settling sludges

1) If settling is sufficiently slow a condition called sludge bulking occurs. Bulking sludges do not settle and do not concentrate

2) Slow settling sludges frequently produce excellent effluents because such sludges clarify very well. However, it may be difficult to maintain the sludge in the clarifier and to prevent solids wash-out

3) Adjust return sludge flow rate to increase the time available for settling and concentration in the final clarifier. Do this by decreasing RSF. Try to achieve an RSC corresponding to the 2-3 hour point on the SSC vs. time curve. This change also increases aeration detention time allowing more time to stabilize the sludge. If the sludge blanket begins to fall after this change, then the correct response has been made

4) If 3 doesn't work, then slowly increase RSF and observe the blanket performance. Operate at RSF which gives lowest blanket

5) It may be necessary to operate for a short period of time with a very high RSF or XSF to lower the sludge blanket and prevent wash-out. RSF or XSF should be held at the high

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

values only as long as it takes to lower the blanket. Once the blanket is under control RSF and XSF should be reduced

6) Adjustments in RSF should be made gradually, no more than 10-25% increase or decrease per day

c. Fast settling sludges

1) Operate at high RSF to prevent solids accumulation in the final clarifier

2) Adjust RSF to achieve an RSC corresponding to the 15-20 minute SSC value on the SSC vs. time graph

Note: Very fast settling sludges may not respond to RSF changes as readily as normal sludges respond to RSF changes. Fast settling sludges are usually old and very stable sludges. The settling characteristics of fast settling sludges may show little or no change as RSF is increased or decreased.

3. Calculation for Desired Clarifier Sludge Flow

a. Formula

Write formula on chalkboard

$$CSFD = CSF \times \frac{RSC - ATC}{SSC_t - ATC}$$

where: CSFD = Desired Clarifier Sludge Flow (Clarifier Sludge Flow Demand)

CSF = Actual (measured) Clarifier Sludge Flow

RSC = Actual (measured) Return Sludge Concentration

ATC = Actual (measured) Aeration Tank Concentration (mixed liquor concentration)

LESSON OUTLINE

SSC_t = Desired RSC value determined from SSC vs. time graph

b. RSF changes should be made gradually (10-25% per day)

c. Formula can be expressed in terms of clarifier sludge flow as a percent of influent flow

d. Centrifuge test estimates of concentration are preferred but any consistent set of units may be used

e. Refer to West, *Updated Summary of the Operational Control Procedures for the Activated Sludge Process*, pages 9 - 10 for an example calculation

B. Wasting Control

1. Normal Sludge

   a. Maintain trend charts of settling test observations (see West, *Operational Control Procedures for the Activated Sludge Process, Appendix*)

   b. Continue present wasting practices until trend change in settling characteristics is observed

      1) Sludge is settling faster - increase wasting

      2) Sludge is settling slower - decrease wasting

      3) Limit wasting rate changes to ± 15% per day

KEY POINTS & INSTRUCTOR GUIDE

Note: Point out problems of using formula. It indicates proper direction of correction but improper magnitude.

Refer class to West, *Updated Summary of the Operational Control Procedures for the Activated Sludge Process*, pages 13-15

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
c. System response to wasting changes is slow - on the order of the MCRT	
1) Low MCRT - faster response	
2) Long MCRT - slower response	
3) System requires time to adjust to new solids inventories and for the sludge quality to change	
2. Fast settling sludge	
a. Usually caused by too much old sludge (long MCRT, very stable sludge)	
b. Increase wasting to reduce solids inventory	
c. Limit wasting changes to ± 15% per day	
d. Sludge concentration effect on settling	
1) Hindered settling	
2) Decrease concentration of sludge and sludge settles faster because there is less interference	
3) Increase concentration of sludge and sludge settles slower because of increased interference	
4) Initially, increase in wasting may cause sludge to settle faster. However, this trend will reverse as the old sludge is replaced with new slower settling sludge	

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

e. Be patient with wasting rate changes. The system needs time to respond. Response time depends on MCRT. Longer the MCRT the slower the response

3. Slow Settling Sludge

a. Sludge concentration control

1) Slow settling may be result of system being glutted with too many solids

2) Dilute mixed liquor with final effluent, if settling rate increases and sludge concentrates better with dilution of solids, then "blast" waste to remove excess solids

3) This is a sludge "quantity", not a sludge "quality," problem

b. Sludge Quality Control

1) Slow settling usually associated with young, high F/M, low MCRT sludges and there are insufficient solids to handle the applied load

2) Decrease wasting to increase the solids inventory

3) If settling tests on diluted sludge samples show improved settling and concentration of the sludge with dilution, then "blast" wasting may be advised

C. Aeration Detention Time Control

1. Stable sludges tend to settle faster and concentrate more than less stable sludges

Refer to West, *Updated Summary of the Operational Control Procedures for the Activated Sludge Process*, pages 15-16

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Increasing sludge aeration time will cause sludge to become more stable and settle faster	
3. Trend to slower settling sludge may indicate need to use sludge reaeration to stabilize sludge more and increase settling rate	
4. Trend to faster settling sludge may indicate need to change from sludge reaeration mode to a conventional mode	
D. Sludge Volume Index	Use Slide 179.2/11.5.29 Slide 179.2/11.5.29 is a blank
1. Test Procedure	
a. Use 1000 ml graduated cylinder as settling test vessel rather than settleometer	
1) Wall effects in 1000 ml cylinder a problem	
2) Settleometer more representative of final clarifier conditions	
3) According to West, one obtains more consistent and reproducible results with settleometer	
b. Test procedure same as for settleometer except normally run test for 30 minutes rather than 60 minutes	
c. Data and observations are similar	
2. Calculations and interpretations	
a. Settled Sludge Volume = volume occupied by sludge in ml per 1000 ml water after 30 minutes settling time	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. Can be used to calculate Sludge Volume Index (SVI) and Sludge Density Index (SDI) $\text{SVI} = \frac{\text{Settled Sludge Volume, ml/l}}{\text{MLSS, mg/l}} \times 1000$ $\text{SDI} = \frac{1}{\text{SVI}}$	Write equations on chalkboard
c. SVI levels are plant-specific, but are typically between 50-150 (extended aeration SVI may range between 25-110) 1) SVI's below 50 indicate a high density sludge with rapid settling 2) SVI's greater than 200 indicate a low density sludge with slow settling (bulking) 3) SSV values can be plotted to evaluate the settling performance of sludge in a manner analogous to settleometer results	
d. Estimating return rate using SVI 1) Definition $\text{RSC} = \frac{1{,}000{,}000}{\text{SVI}}$	Write equation on chalkboard
RSC has units mg/l 2) Calculation of RSF by mass balance around aeration basin $\text{RSF} = \frac{\text{Influent Flow Rate X ATC}}{\text{RSC - ATC}}$	Write equation on chalkboard

LESSON OUTLINE

e. SVI is normally used as a process stability indicator

    1) Decreasing SVI indicates a more stable, faster settling sludge and therefore need to increase wasting

    2) Increasing SVI indicates a less stable, slower settling sludge and therefore need to decrease wasting

f. Disadvantage of SVI control and 30 minute settling test

    1) Considers only a single point on the settling curve to define sludge quality

    2) Works best with fast settling sludges

    3) Assumes that return changes do not affect sludge settling characteristics

    4) Responds to current settling conditions and does not force the system to correct to a more desirable settling condition

    5) Leads to solids accumulation in the final clarifier

E. Recommend West's Sludge Quality Control Procedures as preferable to 30 minute settling test and SVI approach

F. Data Forms - discuss as needed

KEY POINTS & INSTRUCTOR GUIDE

Refer class to *Trainee Notebook* pages T11.5.1-T11.5.8 for summary of data required for sludge quality control and sample data forms

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
VII. Discussion (5 minutes) A. Use remaining time to respond to class questions B. Assign West's pamphlet series as reading assignment	

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 5: Process Control Based on Sludge Settleability

Trainee Notebook Contents

Activated Sludge Process Data for Use With West's Sludge Quality Control Procedures. T11.5.1

Settleometer Test Information T11.5.4

Monthly Data Sheet Information T11.5.5

Monthly Data Sheet T11.5.8

ACTIVATED SLUDGE PROCESS DATA FOR USE WITH WEST'S SLUDGE QUALITY CONTROL PROCEDURES

Samples Required

1. Measure the sludge blanket depth and record value.
2. Collect a return sludge sample (about 500 ml). Also collect a waste sludge sample (about 500 ml) if sludge is not wasted from the return sludge line.
3. Collect a final clarifier effluent sample (about 500 ml).
4. Collect a sample of mixed liquor as it leaves the aeration basin (about 3000 ml).
5. Record influent flow rate, return sludge flow rate and waste sludge flow rate.

Settleometer Test Information

1. Record time the mixed liquor sample was collected from the aeration basin.
2. Set up settleometer test keeping a portion of the mixed liquor sample for the centrifuge test. Record Settled Sludge Volume (SSV) values at settling times given in the table. Observe the sludge blanket formation and the appearance of the supernate liquid. Record your observations.
3. Determine the Aeration Tank Concentration (ATC) using the centrifuge. The Settled Sludge Concentration (SSC) is equal to the ATC at the start of the settleometer test (settling time = 0 and SSV = 1000). Record the ATC in the SSC column in the space for settling time equal to zero and SSV equal to 1000.
4. Calculate SSC values using the formula:

$$SSC = (ATC) \times 1000/SSV$$

5. Determine RSC and XSC (eXcess Sludge Concentration or waste sludge concentration) using the centrifuge test.
6. Let the final effluent sample set quietly for about one hour. Then measure the turbidity of the "settled" effluent.

7. Record time, RSC, DOB, TURB, ATC and RSF in spaces provided.

8. If several samples are collected and analyzed during the day, enter data for each sample on a separate line in the table. At the end of the day calculate the average values for RSC, DOB, TURB, ATC and RSF and record these values in the appropriate columns on the Monthly Data Sheet.

Additional Information

1. Get the aeration tank volume in MG, the final clarifier volume in MG and the average depth of the clarifier in feet from the plans and specifications or the O & M manual and record them on the data sheet.

2. Once each day measure the MLSS gravimetrically and calculate the spin ratio.

$$\text{Spin Ratio} = \frac{\text{MLSS Concentration (mg/l)}}{\text{ATC (\%)}}$$

Wasting Information

1. Enter time wasting began and time wasting ended in the table.

2. Calculate total time wasted in minutes.

3. Record the eXcess Sludge Flow (XSF) rate or wasting flow rate in gallons per minute (GPM).

4. Calculate the total gallons wasted.

5. Collect two waste sludge samples (about 500 ml each), one at the start and one at the end of the wasting period. Determine XSC on each sample using the centrifuge and record the data in the columns provided. (If you waste from the return sludge line, then the XSC will be the same as the RSC. If you waste from the aeration basin, then the XSC will be the same as the ATC.)

6. Calculate the average XSC as $\frac{\text{(XSC Begin + XSC Ended)}}{2}$ and record the average XSC.

7. Calculate the sludge units wasted (the eXcess Sludge Units, XSU) using the formula:

$$\text{XSU} = \frac{\text{Gallons Wasted}}{1{,}000{,}000} \times \text{Average XSC (\%)}$$

and record in the column provided.

8. If wasting is accomplished two or more separate wasting periods each day, then collect all data and calculate XSU for each wasting period. The total XSU per day will be the sum of the XSU from each wasting period. Record the total XSU in column 13 on the Monthly Data Report.

SETTLEOMETER TEST INFORMATION

TIME OF TEST		
TIME	SSV CC/L	SSC%
0		
5		
10		
15		
20		
25		
30		
40		
50		
60		

TIME OF TEST		
TIME	SSV CC/L	SSC%
0		
5		
10		
15		
20		
25		
30		
40		
50		
60		

TIME OF TEST		
TIME	SSV CC/L	SSC%
0		
5		
10		
15		
20		
25		
30		
40		
50		
60		

$$SSC = \frac{(ATC)\ (1000)}{SSV}$$

DATE	TIME	RSC	DOB	TURB	ATC	RSF
		%	FT		%	MGD
AVERAGE						
				TOTAL		

ADDITIONAL INFO.

AERATION TANK VOLUME MG.

CLARIFIER VOLUME MG.

AVG. DEPTH OF CLAR. FT.

SPIN RATIO MG/L = 1%

WASTING INFORMATION

TIME WASTING BEGAN	TIME WASTING ENDED	TOTAL TIME WASTED (MIN)	FLOW RATE (GPM)	GALLONS WASTED (GAL)	XSC BEGAN (%)	XSC ENDED (%)	AVG. XSC (%)	SLUDGE UNITS WASTED MG.%

Monthly Data Sheet

COLUMN #	HEADING (ABBREVIATION)	MEANING	DATA OR CALCULATION REQUIRED
1	DAY		Enter the day of the week, i.e. Sunday, Monday, Tuesday, etc.
2	DATE		
3	ATC	Aeration Tank Concentration	The concentration of mixed liquor suspended solids measured by centrifuge and reported as % solids.
4	ASU	Aeration Sludge Units	An estimate of the total quantity of activated sludge solids in the aeration basin defined as the aeration tank volume in MG times the aeration tank concentration in %. ASU = Aeration Basin Volume (MG) x ATC (%)
5	DOB	Depth Of Blanket	The distance measured in feet from the surface of the water in the final clarifier to the top of the sludge blanket.
6	CSU	Clarifier Sludge Units	An estimate of the total quantity of activated sludge solids in the final clarifier defined as the volume occupied by the final clarifier sludge blanket in MG times the average solids concentration in the sludge blanket in %. $\text{CSU} = \text{Volume of Final Clarifier (MG)} \times \left(1 - \frac{\text{DOB}}{\text{Ave. Depth of Clarifier}}\right) \times \frac{(\text{ATC} + \text{RSC})}{2}$
7	TSU	Total Sludge Units	An estimate of the total quantity of activated sludge solids in the system. TSU = ASU + CSU

COLUMN #	HEADING (ABBREVIATION)	MEANING	DATA OR CALCULATION REQUIRED
8	RSC	Return Sludge Concentration	The concentration of activated sludge solids in the return sludge measured by centrifuge and reported as % solids.
9	RSF	Return Sludge Flow	The return sludge flow rate in MGD
10	RSU	Return Sludge Units	An estimate of the total quantity of activated sludge solids which are being circulated through the aeration basin and final clarifier each day defined as the return sludge flow in MG times the return sludge concentration in % solids.
11	TURB	Turbidity	The turbidity of the effluent overflow from the final clarifier as measured with a turbidimeter.
12	ESU	Effluent Sludge Units	An estimate of the total suspended solids in the effluent overflow from the final clarifier which are lost from the system each day. ESU = FLO (MGD) x Effluent TSS (mg/l) ÷ Spin Ratio (mg/l/%)
13	XSU	eXcess Sludge Units	An estimate of the total quantity of activated sludge solids deliberately wasted from the system each day defined as the waste sludge flow (MGD) times the waste sludge concentration (% solids)
14	WSU	Waste Sludge Units	An estimate of the total quantity of activated sludge units lost from the system each day. WSU = ESU + XSU

COLUMN #	HEADING (ABBREVIATION)	MEANING	DATA OR CALCULATION REQUIRED
15	MCRT	Mean Cell Residence Time	An estimate of the average time in days that a unit of activated sludge solids stays in the system. $\text{MCRT (day)} = \frac{\text{TSU (MG \%)}}{\text{WSU (MG \%/day)}}$
16	SDT_c	Sludge Detention Time in the Clarifier	An estimate of the time in hours that an average unit of activated sludge stays in the final clarifier each day. $SDT_c\ \text{(hr)} = \frac{\text{CSU (MG \%)}}{\text{RSU (MG \%)}} \times 24$
17	SDT_a	Sludge Detention Time in the Aeration Basin	An estimate of the time in hours that an average unit of activated sludge stays in the aeration basin each day. $SDT_a = \frac{\text{ASU (MG \%)}}{\text{RSU (MG \%)}} \times 24$
18	FLO	Flow Out of Final Clarifier	The effluent overflow from the final clarifier in MGD. Approximately equal to the raw sewage influent flow rate in MGD.

MONTHLY DATA SHEET

MONTH ____________ YEAR ________ SOURCE ____________________

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
DAY	DATE	ATC	ASU	DOB	CSU	TSU	RSC	RSF	RSU	TURB	ESU	XSU	WSU	MCRT	SDT_C	SDT_A	FLO
		%	MG%	FT	MG%	MG%	%	MGD	MG%		MG%	MG%	MG%	DAY	HR.	HR.	MGD
	1																
	2																
	3																
	4																
	5																
	6																
	7																
	8																
	9																
	10																
	11																
	12																
	13																
	14																
	15																
	16																
	17																
	18																
	19																
	20																
	21																
	22																
	23																
	24																
	25																
	26																
	27																
	28																
	29																
	30																
	31																

T11.5.8

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 6: Respiration Rate Control Procedures

Lesson 6 of 14 lessons Recommended Time: 60 minutes

Purpose: Respiration Rate or specific oxygen uptake rate is a rapid, relatively easy procedure to monitor the biological activity in activated sludge systems. Respiration rate observations correlate well with process conditions, sludge settling qualities and final effluent quality. Respiration rate provides a very useful process evaluation and control tool which can be used in conjunction with F/M, MCRT and sludge settleability data to identify process problems, to determine problem causes and to guide corrective responses. The troubleshooter must understand and be able to use respiration rate determinations in technical assistance projects.

Trainee Entry Level Behavior: The trainee should have completed Unit 11, Lessons 1-5, and achieved the learning objectives for these lessons before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. From memory, define respiration rate.

2. From memory, list the equipment needed to determine respiration rates and describe the test procedures.

3. From memory, list three different wastewater activated sludge solids mixtures for which respiration rates should be measured and explain how the results can be used in process control, process evaluation and process troubleshooting.

4. From memory, describe how respiration rate data correlate with F/M, MCRT and sludge settleability process control data.

Instructional Approach: Illustrated lecture with class discussion.

Lesson Schedule: The 60 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 5 minutes	Importance of Respiration Rate in Process Control
5 - 15 minutes	Respiration Rate Test Procedure
15 - 35 minutes	Significance of Mixed Liquor Respiration Rate
35 - 50 minutes	Significance of Fed Sludge Respiration Rate
50 - 55 minutes	Significance of Final Effluent Oxygen Uptake Rate
55 - 60 minutes	Summary and Discussion

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T11.6.1 - T11.6.9 , "Respiration Rate Control Procedures."

2 *Operators Pocket Guide to Activated Sludge, Parts I and II*, STRAAM Engineers, Inc., Portland, Oregon (1974).

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 11, Lesson 6, pages 11.6.1 - 11.6.27.

2. Slides 179.2/11.6.1 - 179.2/11.6.49.

Instructor Materials Recommended for Development: None

Additional Instructor References:

1. Ludzack, F. J., "Dissolved Oxygen Analysis--Activated Sludge Control Testing," slide-tape XT-43, U. S. Environmental Protection Agency, National Training and Operational Technology Center, Cincinnati, Ohio (1971).

2. Johnson, D. S. et. al, "Operational Control of an Activated Sludge Process by Biomass Respiration Rate," presented at 44th Annual Pacific Northwest Pollution Control Association Meeting, Portland, Oregon (November 2-4, 1977).

3. Johnson, D.S., Bhagat, S.K., Asano, T., and Ongerth, J.E., "Operation of an Activated Sludge Process Using Biomass Respiration Rates to Accommodate Fluctuating Hydraulic and Organic Loads," Final Report, Dept. of Civil and Environmental Engineering, Washington State University, Pullman, Washington (July, 1976).

4. Benefield, L. D., Randall, C.W., and King, P. H., "Process Control by Oxygen - Uptake and Solids Analysis," *Journal Water Pollution Control Federation*, 47 , 2498 (October, 1975).

5. Joyce, R. J., Ortman, C., Zickefoose, C., "Optimization of an Activated Sludge Plant Using TOC, Dissolved Oxygen, Respiration Rate and Sludge Settling Volume Data," presented at the WWEMA Ind. Water and Pollution Conference, Detroit, Michigan (April, 1974).

6. Hegg, B.A. and Burgeson, J. R., "An Integrated Approach to Control Testing and Basic Kinetics," presented at 47th WPCF Conference, Denver, Colorado (October, 1974).

Classroom Set-Up: As specified in Unit 11, Lesson 1.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Importance of Respiration Rate in Process Control (5 minutes)	Use Slide 179.2/11.6.1 Slide 179.2/11.6.1 is a blank

I. Importance of Respiration Rate in Process Control (5 minutes)

A. Activated sludge objective is to produce settleable solids and a stabilized effluent

1. Sludge settleability affected by many factors

   a. Influent load

   b. Quantity of solids under aeration (solids inventory)

   c. Aeration time

   d. Type of organics in sludge solids

   e. Adequate nutrients and D.O.

   f. Mixing

   g. Presence of toxic or inhibitory substances

   h. Temperature

   i. Others

2. Sludge quality (settleability) and effluent quality vary with sludge stability (biological activity)

   a. Overstabilized sludge produces fast settling sludge but high effluent turbidity (poor clarification)

   b. Under stabilized sludge produces slow settling, good clarification (sometimes) but are hard to keep in the final clarifier and may produce a high effluent BOD

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

c. Best sludge quality, effluent quality and overall system performance obtained at some intermediate level of sludge stability

3. Control procedures looked at so far (F/M, MCRT and sludge settleability) are not direct measure of sludge stability but are guides to control process variables in ranges which are known to produce properly stabilized sludges. Of the three, the sludge settleability is the only one which directly measures and responds to sludge quality changes

4. The specific oxygen uptake rate or the respiration rate, defined as mg oxygen used per hour per gram MLSS, is a direct measure of biological activity and hence a direct indicator of sludge stability

Write definition on chalkboard

5. Respiration rate control provides means to respond directly and quickly to changes in sludge stability

B. Respiration Rates Measured

1. Mixed liquor suspended solids at effluent from aeration basin

2. Mixture of return sludge and final effluent

3. Mixture of return sludge and aeration basin influent

4. Final effluent (simply an oxygen uptake rate, not a respiration rate)

C. Respiration rates of the MLSS and the return sludge and aeration basin influent are most useful in process control and troubleshooting

LESSON OUTLINE

D. Lesson Objectives

1. Explain respiration rate test procedures
2. Explain use of respiration rate measurements in process control and troubleshooting
3. Relate respiration rate results to other process control parameters (F/M, MCRT and sludge settleability)

II. Respiration Rate Test Procedures (10 minutes)

A. Apparatus

1. Sampling Bottles
    a. 1000 ml samples
    b. Sample locations
        1) Aeration basin effluent
        2) Return sludge
        3) Final effluent
        4) Aeration basin influent
            a) Raw waste or
            b) Primary effluent
2. Graduated Cylinders
    a. Assorted 100, 250 and 500 ml
    b. Used to measure aliquots for sample mixtures
3. BOD Bottles and Adapter
    a. Needed when using D.O. Analyzer self-stirring probe
    b. 500 ml Erlenmeyer flasks required if using D.O. Analyzer with field probe

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.6.2

Slide 179.2/11.6.2 is a word slide which reads:

"Apparatus

- Sampling Bottles
- Graduated Cylinders
- BOD Bottles and Adapter
- Magnetic Stirrer
- Timer
- D.O. Analyzer"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
4. Magnetic Stirrer and Stirring Bars a. Provide mixing to keep sludge solids in suspension b. Self-stirring BOD probe not adequate to keep sample solids in suspension	
5. Timer a. Data recorded at one minute intervals for 10-15 minutes b. Accurate time c. Long sweep and large one minute incremental markings	
6. D.O. Analyzer a. Equipped with self-stirring BOD probe preferred b. Can use alternate procedure using field probe but suffer some loss in accuracy and precision	
7. Use Slide 179.2/11.6.3 to illustrate apparatus	Use Slide 179.2/11.6.3 Slide 179.2/11.6.3 is a photograph showing the apparatus for the respiration rate test procedure
B. Test Procedure	
1. Calibrate D.O. Analyzer	Use Slide 179.2/11.6.4 Slide 179.2/11.6.4 is a word slide which reads "Calibrate D.O. Analyzer"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Collect samples a. Representative b. Fresh	Use Slide 179.2/11.6.5 Slide 179.2/11.6.5 is a photograph showing aeration basin effluent sample Use Slide 179.2/11.6.6 Slide 179.2/11.6.6 is a photograph showing primary effluent, return sludge and secondary effluent samples
3. Shake sample to aerate and saturate with D.O.	Use Slide 179.2/11.6.7 Slide 179.2/11.6.7 is a photograph showing technician aerating sample
4. Pour aerated sample into BOD bottle. Fill bottle	Use Slide 179.2/11.6.8 Slide 179.2/11.6.8 is a photograph showing technician filling the BOD bottle
5. Place stirring bar and BOD probe into bottle	Use Slide 179.2/11.6.9 Slide 179.2/11.6.9 is a photograph showing technician placing the stirring bar and probe into the bottle
6. Start stirrer and adjust speed to maintain uniform solids suspension	Use Slide 179.2/11.6.10 Slide 179.2/11.6.10 is a photograph showing technician adjusting mixing speed
7. Set timer to 10 minutes	Use Slide 179.2/11.6.11 Slide 179.2/11.6.11 is a photograph showing technician setting the timer
8. Observe and record a. Initial temperature (test is very sensitive) b. Initial D.O. c. D.O. every minute	Use Slide 179.2/11.6.12 Slide 179.2/11.6.12 is a word slide which reads "Observe and Record · Initial Temperature · Initial D.O. · D.O. Every Minute"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
d. Refer class to *Trainee Notebook*, page T11.6.9 , "Sample Data Sheet for Respiration Rate Determination"	Use Slide 179.2/11.6.13 Slide 179.2/11.6.13 is a photograph showing technician recording data on the data form
9. Record D.O. every minute	Use Slide 179.2/11.6.14-179.2/11/6/17 Slides 179.2/11.6.14-179.2/11.6.17 are photographs of D.O. Analyzer dial taken at approximately one minute intervals
a. Accurate time intervals	
b. Usually observe very large D.O. depletions in first one to two minutes of test	
c. Continue until	
1) Four consecutive readings show constant D.O. Depletion rate (change per minute constant)	
2) D.O. is depleted	
10. Measure and record solids concentration	Use Slide 179.2/11.6.18 Slide 179.1/11.6.18 is a blank
a. Gravimetric solids preferred	
b. Can use centrifuge spins to estimate solids	
11. Perform Calculations	Refer class to *Trainee Notebook*, page T11.6.9 , "Sample Data Sheet for Respiration Rate Determination"
a. Review sample identification information	
b. Recordings of D.O.	
c. Calculate ΔD.O.	
d. Use portion of test which yields four consecutive ΔD.O./minute readings which are constant. This is ΔD.O./minute used in calculation of RR	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
1) Alternate procedure is to graph D.O. readings and take slope of straight line portion of the curve as ΔD.O./minute for the test	
e. Calculate ΔD.O./hr	
$\Delta D.O./hr = \Delta D.O./min \times 60\ min/hr$	
f. Calculate Respiration Rate	
1. $RR = \frac{\Delta D.O./hr}{MLSS\ (mg/l)} \times \frac{1000\ mg}{gm}$	
2. $RR = \frac{\Delta D.O.\ hr}{MLSS\ (gm/l)}$	
3. RR = mg Oxygen used/hr/gm	
C. Alternate Test Procedures	
1. Aeration of sample using BOD bottles	
a. Place aerated sample in BOD bottle	
b. Use BOD bottle adapter and empty BOD bottle as shown	Use Slide 179.2/11.6.19 Slide 179.2/11.6.19 is a photograph showing BOD Bottle with sample connected to empty BOD Bottle using the BOD bottle adapter
c. Aerate by transferring the sample between BOD bottles	Use Slide 179.2/11.6.20 Slide 179.2/11.6.20 is a photograph showing technician aerating the sample
d. Perform remainder of test as described in II.B.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Procedure Using Erlenmeyer Flask and Field Probe	
a. Reason for Alternate Procedure 1) Many plants do not have a self-stirring BOD probe for the D.O. analyzer because these probes are expensive (about $300 in 1979) 2) Many plants do have D.O. analyzer with field probe for determining D.O. in the aeration basin influent, final effluent, etc.	Use Slide 179.2/11.6.21 Slide 179.2/11.6.21 is a photograph showing Erlenmeyer flask and field probe for D.O. analyzer
b. Procedure is the same as given in II.B. except that aerated sample is placed in 500 ml Erlenmeyer flask rather than in a BOD bottle	Use Slide 179.2/11.6.22 Slide 179.2/11.6.22 is a photograph showing an operator performing oxygen uptake test using Erlenmeyer flask alternate procedure
c. Precautions 1) Erlenmeyer flask must be completely filled 2) Rubber stopper is used to adapt probe to flask and provide air tight seal	
d. Limitations 1) May get false readings if there is air space in the sample bottle during the test procedure	
D. Sample preparation and test procedures for determining RR of various return sludge wastewater mixtures will be discussed later in sections on interpretation of results	Use Slide 179.2/11.6.23 Slide 179.2/11.6.23 is a blank

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
1. Unfed sludge sample - mixture of return sludge and primary effluent	
2. Fed sludge sample - mixture of aeration basin influent wastewater and return sludge	
3. Final effluent oxygen uptake rate	
III. Significance of Mixed Liquor Respiration Rate (20 minutes)	
A. Sample used is the aeration basin effluent	
B. Monitors stability of the mixed liquor solids as they enter the final clarifier	Use Slide 179.2/11.6.24 Slide 179.2/11.6.24 is a word slide which reads:
1. Stability monitored as RR	
2. Respiration Rate correlates with	"Significance of Aeration Basin Mixed Liquor Respiration Rate
a. Sludge settleability, clarification and concentration characteristics	· Monitors stability of mixed liquor solids · Correlates with: ·Sludge Settleability
b. BOD removal in system	·BOD Removal
c. Organic loading to aeration basin	·Organic Loading ·Detention Time ·Solids Inventory"
d. Aeration basin detention time	
e. Sludge aeration time	
f. Solids inventory	
C. Uses	Use Slide 179.2/11.6.25 Slide 179.2/11.6.25 is a word slide which reads
1. Determine adjustments in return rate	
2. Determine adjustments in wasting	"Uses of Aeration Basin Mixed Liquor Respiration Rate Data
3. Determine adjustments in aeration detention time	· Adjust return sludge rates

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
4. Respond to organic load changes 5. Determine reaeration requirements	·Adjust wasting rates ·Respond to aeration basin detention time changes ·Respond to organic loading changes ·Determine reaeration requirements"
D. Interpretation of RR Data 1. Normal range for aeration basin mixed liquor RR is 12-20 mg/hr/gm a. System is balanced producing 1) Good BOD removal 2) Good settleability 3) Good clarification 4) Good sludge concentration	Use Slide 179.2/11.2.26 Slide 179.2/11.6.26 is a word slide which reads: "Aeration Basin Effluent Respirarate Rate Normal Range 12-20 mg/hr/gm Good BOD Removal Good Settleability Good Clarification Good Sludge Concentration"
b. Process control procedures are good and operation should be continued following current procedures c. Optimum respiration rate is plant specific. Range given should be used as a guide not an absolute range for all plants	
2. Respiration rate is high - greater than 20 mg/hr/gm a. Sludge characteristics 1) Under stabilized 2) Slow settling - extreme case is sludge bulking 3) Poor concentration	Use Slide 179.2/11.6.27 Slide 179.2/11.6.27 is a word slide which reads: "Aeration Basin Effluent Respiration Rate High Greater than 20 mg/hr/gm Sludge Under stabilized Slow settling Concentrates poorly

LESSON OUTLINE

b. Possible Causes

   1) Organic overload (F/M high)

   2) Low solids inventory (short MCRT)

   3) Short aeration detention time

   4) Inadequate solids aeration time

c. Results

   1) Possible high effluent BOD & TSS

   2) Sludge blanket rises

   3) Possible solids wash-out from final clarifier

   4) Diluted return sludge concentration

   5) High O_2 uptake could cause clarifier to become septic

d. Conditions are such that the process will continue to deteriorate unless corrective actions are taken

3. Respiration rate is low - less than 12 mg/hr/gm

   a. Sludge characteristics

      1) No toxic load

         a) Over stabilized

         b) Fast settling

         c) Concentrates rapidly

KEY POINTS & INSTRUCTOR GUIDE

Possible Causes
High F/M
Low Solids Inventory (short MCRT)
Short Aeration Detention Time
Inadequate Solids Aeration Time

Results
Possible High Effluent BOD & TSS
Sludge Blanket Rises
Possible Solids Washout
Dilute Return Sludge Concentration
Possible Septic Conditions"

Use Slide 179.2/11.6.28

Slide 179.2/11.6.28 is a word slide which reads:

"Aeration Basin Effluent Respiration Rate

Low Less than 12 mg/hr/gm

Sludge
Over Stabilized
Fast Settling
Concentrates Rapidly

LESSON OUTLINE

2) Toxic load

   a) Deflocculation

   b) Dispersed (no flocculation)

   c) Slow settling

   d) Poor concentration

b. Possible Causes

   1) Organic underloading (Low F/M)

   2) High solids inventory (long MCRT)

   3) Long aeration detention time

   4) Too long solids aeration time

   5) Toxic load

c. Results

   1) High effluent TSS possible

   2) Sludge blanket falls

   3) Poor clarification

   4) Concentrated return sludge

   5) Nitrification/denitrification potential high

   6) Pin floc or ashing

E. Process Control Responses to MLSS RR

1. Respond to RR rate trends

   a. Balance (optimize) system and determine acceptable RR operating range

KEY POINTS &
INSTRUCTOR GUIDE

Possible Causes:
- Low F/M
- High Solids Inventory (Long MCRT)
- Long Aeration Detention Time
- Too Much Solids Aeration Time
- Toxic Load

Results:
- Possible High Effluent TSS
- Sludge Blanket Falls
- Poor Clarification
- Concentrated Return Sludge
- Possible Nitrification/Denitrification
- Pin Floc or Ashing"

Use Slide 179.2/11.6.29

Slide 179.2/11.6.29 is a word slide which reads

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. Prepare and maintain RR Trend Charts	"Routine Process Control Using Respiration Rate Data
c. Respond to RR Trend changes 1) Detect changes before serious problems occur 2) Make only one change at a time	Optimize system Determine Optimum RR Operating Range Maintain RR Trend Charts Respond to Trend Changes Make Only One Change at a Time"
2. Responses to MLSS RR Trends When Operating With Normal or Slowly Settling Sludges	Use Slide 179.2/11.6.30 Slide 179.2/11.6.30 is a word slide which reads:
a. MLSS RR Increasing 1) Decrease return rate 2) Decrease waste rate	"Control Responses to Mixed Liquor Respiration Rate Trends Condition: Normal or Slowly Settling Sludge
3) Increase sludge aeration time b. MLSS RR Decreasing 1) Increase return rate 2) Increase waste rate 3) Decrease sludge aeration time	RR Increasing: Decrease Return Rate Decrease Waste Rate Increase Sludge Aeration Time RR Decreasing: Increase Return Rate Increase Waste Rate Decrease Sludge Aeration Time"
c. Make only one change at a time d. Rationale: Control responses will significantly affect sludge settling characteristics	
3. Response to MLSS RR Trends when operating with a fast settling sludge and a final clarifier sludge blanket	Refer to *Instructor Notebook*, Unit 11, Lesson 2, Section II, pages 11.2.7-11.2.16
a. MLSS RR Increasing 1) Increase return rate to move solids from clarifier to aeration basin	Use Slide 179.2/11.6.31 Slide 179.2/11.6.31 is a word slide which reads:

LESSON OUTLINE

  - 2) Decrease waste rate to increase solids inventory
  - 3) Increase sludge aeration time

- b. MLSS RR Decreasing
  - 1) Decrease return rate to allow solids to accumulate in the final clarifier
  - 2) Increase wasting to reduce the solids inventory
  - 3) Decrease sludge aeration time
- c. Make only one change at a time
- d. Rationale: Sludge is probably significantly over stabilized (over oxidized) such that changes in control parameters have no significant impact on sludge settling and concentration characteristics

IV. Significance of Fed Sludge Respiration Rate (15 minutes)

A. Correcting Major Process Imbalances

1. Troubleshooter normally sees plants that are grossly upset and is seldom called into a plant that is operating well or that is only mildly upset.
2. Troubleshooter will usually see system when:
   - a. MLSS RR is either very high or very low
   - b. F/M is either very high or very low
   - c. MCRT is either very long or very short

KEY POINTS &
INSTRUCTOR GUIDE

"Control Responses to Mixed Liquor Respiration Rate Trends

Condition
Fast Settling Sludge
Final Clarifier Sludge Blanket

RR Increasing	Increase Return Rate Decrease Waste Rate Increase Sludge Aeration Time
RR Decreasing	Decrease Return Rate Increase Waste Rate Decrease Sludge Aeration Time"

LESSON OUTLINE

d. Solids inventory is either very large or very small

e. Aeration detention times are either very long or very short

f. System is repeatedly upset and operating staff cannot establish or maintain good process balance and performance

3. Troubleshooter must

   a. Evaluate design and past operating data

   b. Characterize the influent waste

   c. Determine process conditions

      1) F/M

      2) MCRT

      3) Sludge Settleability

      4) Respiration Rates

   d. Determine cause of problem

   e. Recommend corrective action

4. Next section of lesson introduces the use of other respiration rates which can aid the troubleshooter in problem identification, determination of problem cause and selection of correct responses to solve the problem

B. Unfed Sludge Respiration Rate

1. Respiration rate of a mixture of return sludge and final effluent is used to determine the condition of the sludge after aeration and settling

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.6.32
Slide 179.2/11.6.32 is a word slide which reads:

"Correcting Major Process Imbalance

Evaluate Design and Past
  Operating Data
Characterize Influent Waste
Determine Process Conditions
  F/M
  MCRT
  Sludge Settleability
  Respiration Rates
  Detention Times
Determine Cause of Problem
Recommend Corrective Action"

Use Slide 179.2/11.6.33
Slide 179.2/11.6.33 is a word slide which reads:

LESSON OUTLINE

2. Measures sludge condition as it is returned to the head of aeration tank

3. Biological activity continues in the final clarifier

   a. Possible further stabilization of the sludge because there is no food available

   b. Anoxic or anaerobic conditions in the final clarifier could result in start of anaerobic metabolism

   c. Possible endogenous metabolism of storage products releasing "food" supply to sludge

   d. Therefore, return sludge condition may be different from the mixed liquor solids which enter the final clarifier

4. Unfed sludge respiration rate test procedure

   a. Sample preparation

      1) Mix return sludge with final effluent

      2) Proportion return sludge and final effluent to yield mixture that would be same as the aeration basin influent - return sludge mixture

      3) Always use 1000 ml final effluent then add the volume of return sludge needed to give a mixture corresponding to the influent waste - return sludge entering the aeration basin.

      4) Mix thoroughly

      5) Place mixture in RR test vessel

KEY POINTS & INSTRUCTOR GUIDE

"Unfed Sludge Respiration Rate

Sample: Return Sludge +
Final Effluent

Sample Proportions:

$$\frac{\text{Vol Return Sludge}}{\text{Vol Final Effluent}} = \frac{\text{Return Sludge Flow Rate}}{\text{Influent Flow Rate}}$$

Measures:

Condition of Sludge After Aeration and Settling"

Note: ml Return Sludge Needed =

$$\frac{\text{Return Sludge Flow Rate}}{\text{Influent Flow Rate}} \times 1000$$

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
6) Run test as described previously	Refer to pages 11.6.6 - 11.6.10
7) Measure return sludge solids concentration and calculate concentration in mixed sample	
8) Calculate respiration rate	
5. Interpretation of unfed sludge RR	
a. Normal range is 7-16 mg/hr/gm for MLSS equal to 2500 mg/l	
b. Unfed rate follows the load during the day	
1) High organic or hydraulic load: unfed sludge RR increases	
2) Low organic or hydraulic load: unfed sludge RR decreases	
c. Low unfed RR may indicate	
1) Causes	
a) Overoxidized sludge b) Fast settling and good compaction c) Long aeration detention time d) Old sludge e) Toxic load	
2) Effects on process	
a) Same as for low MLSS RR	Refer to pages 11.6.14 - 11.6.15
3) Control Responses	
a) Same as response to low MLSS RR	Refer to pages 11.6.16 - 11.6.17
d. High unfed sludge RR	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
1) Causes a) Under stabilized sludge b) Slow settling and poor compaction c) Organic overloading d) Hydraulic overloading e) Low solids inventory f) High F/M g) Low MCRT h) Short aeration time	
2) Effect a) Same as high MLSS RR	Refer to pages 11.6.13 - 11.6.14
3) Control Responses a) Same as high MLSS RR	Refer to pages 11.6.16 - 11.6.17
e. Primary uses of unfed sludge RR	
1) Identify adverse conditions in final clarifier (anoxic or septic conditions)	
2) Base for evaluating influent load and feed acceptability	
3) Determine condition of return sludge	
C. Fed Sludge Respiration Rate	Use Slide 179.2/11.6.34
1. Measures respiration rate of a mixture of return activated sludge and influent wastewater fed to the aeration basin	Slide 179.2/11.6.34 is a word slide which reads: "Fed Sludge Respiration Rate
2. Expect the fed sludge RR to be higher than the unfed sludge RR because food is available	Sample: Return Sludge + Aeration Basin Influent
3. Fed sludge RR indicates the quantity and nature of the organic load applied to the aeration basin	Sample Proportions: $\frac{\text{Vol Return Sludge}}{\text{Vol Influent}} = \frac{\text{Return Sludge Flow Rate}}{\text{Influent Flow Rate}}$
a) A quick way to estimate influent BOD	

LESSON OUTLINE

b. A quick way to identify toxics in the applied load

c. A quick way to determine feed acceptability

d. A quick way to determine oxygen transfer requirements in the aeration basin

   1) Plant may impose limit on oxygenation capacity

      a) Most aeration tanks with good O_2 transfer will handle O_2 uptake rates of 2.0 - 2.5 mg O_2/l/min

      b) Step feed to distribute load

      c) Improve tank mixing, modify aerator placement

4. Sample preparation and test procedures are the same as for the unfed sludge RR test except that aeration basin influent wastewater is substituted for final effluent in the sample preparation step

D. Load Factor

1. Ratio of fed sludge activity to unfed sludge activity

2. $LF = \frac{\text{Fed Sludge RR}}{\text{Unfed Sludge RR}}$

3. Indicates activity before and after feeding

4. Good sludge and acceptable feed increases oxygen uptake - load factor > 1.

KEY POINTS & INSTRUCTOR GUIDE

Measures:

Organic Load Applied to Aeration Basin"

Use Slide 179.2/11.6.35

Slide 179.2/11.6.35 is a word slide which reads:

"Load Factor

$\text{Load Factor} = \frac{\text{Fed Sludge RR}}{\text{Unfed Sludge RR}}$"

Use Slide 179.2/11.6.36

Slide 179.2/11.6.36 is a word slide which reads:

LESSON OUTLINE

5. Other cases
   a. LF < 1, inhibitory or toxic load
   b. 1 < LF < 2, dilute or stable load
   c. 2 < LF < 5, acceptable loading
   d. LF > 5, possible oxygen supply problems
6. Feed Acceptability
   a. Toxic load will depress fed rate relative to unfed sludge rate
      1) Treatment will suffer
      2) Try coagulation or powered activated carbon treatment
      3) If toxic loads are repeated, identify problem areas along collection system
      4) If feed is suspect, check by using acceptable feed (such as dextrose or sucrose) to determine if low activity is due to feed or sludge
   b. Small increase can be due to dilute feed, poor quality feed, sick sludge or unfavorable conditions
7. Frequent monitoring of Fed Sludge RR permits early detection of load changes and control response before conditions get out of hand

E. Stabilization Time Test (Optional)

KEY POINTS & INSTRUCTOR GUIDE

"Interpretation of Load Factor

LF < 1	Inhibitory or Toxic Load
1 < LF < 2	Dilute or Stable Load
2 < LF < 5	Acceptable Load
LF > 5	Potential O_2 Supply Problem'

Use Slide 179.2/11.6.37
Slide 179.2/11.6.37 is a blank

Use Slide 179.2/11.6.38
Slide 179.2/11.6.38 is a word slide which reads:

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
1. Reflect sludge activity during aeration cycle a. Use slide 179.2/11.6.38 to indicate information obtained from stabilization time test results	"Stabilization Time Tests Indicate Events in Progression after Feeding Possible Lags Irregular Progression or Phases Extended Time Requirements Excessive Peak Uptake Rates"
2. Normal Sequence of events in aeration cycle	
a. Before feeding, the uptake rate is equal to the unfed sludge uptake rate	Use Slide 179.2/11.6.39 Slide 179.2/11.6.39 is a graph showing time progression of oxygen uptake rate with a normal activated sludge process feed
b. After feeding, the rate (ΔD.O./min) usually rises and then decreases as the mixture is stabilized	
c. As stabilization proceeds: 1) Oxygen uptake rate decreases 2) Flocculation tendencies increase 3) Settling rate increases 4) Solids-liquid separation improves	
d. There is some intermediate stabilization range that gives the best effluent quality	
3. Stabilization time test may indicate that sludge requires additional aeration time to acclimate to a new feed	Use Slide 179.2/11.6.40 Slide 179.2/11.6.40 is a graph showing time progression of oxygen uptake rate with 90 minute lag phase while sludge acclimates to the feed
4. Test Procedure a. Determine unfed sludge uptake rate as before	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. Mix and aerate R.S. and wastewater feed in a small tank or bucket (in same proportions as in aeration basin)	
c. At t = 0, draw off sample for uptake test (pour back into tank after determining ΔD.O.)	
d. Repeat c. every 10 or 15 minutes until the new uptake rate approaches the initial unfed rate	
e. Plot oxygen uptake rate (ΔD.O./min) vs. time (min.)	
5. Results permit operator to determine	
a. Aeration time adequacy	
b. Excessive oxygen demands	
c. Effect of new load, etc.	
d. Effect of seasonal changes	
V. Final Effluent Oxygen Uptake Rate (5 minutes)	Use Slide 179.2/11.6.41 Slide 179.2/11.6.41 is a word slide which reads:
A. Measure oxygen uptake of final effluent (final clarifier overflow) prior to chlorination	"Effluent Oxygen Uptake"
B. Use undiluted final effluent. Add no return sludge or other seed organisms	
C. Record as an oxygen uptake rate (OUR), mg/l/hr	
D. Test used to	Use Slide 179.2/11.6.42 Slide 179.2/11.6.42 is a word slide which reads
1. Give quick estimate of final effluent BOD (4 hours test time)	"Effluent Quality
2. Correlate final effluent OUR with final effluent BOD determination	The BOD test is a long term effluent quality index

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. Not suitable for NPDES reporting but useful in process control	ΔD.O.(100% sample) at 15 to 30 minute intervals gives an effluent quality index in less than 4 hours"
VI. Summary and Discussion (10 minutes)	Use Slide 179.2/11.6.43 Slide 179.2/11.6.43 is a word slide which reads: "Summary"
A. Characteristics of Specific Oxygen Uptake Rate (Respiration Rate) Test Results	Use Slide 179.2/11.6.44 Slide 179.2/11.6.44 is a word slide which reads: "Respiration Rate Concentration (MLSS) Independent Units - mg O_2/hr/gm Optimum MLSS RR 12-20"
B. Optimum Range is Plant Specific	Use Slide 179.2/11.6.45 Slide 179.2/11.6.45 is a word slide which reads: "Activated Sludge Mixed Liquor Respiration Rate Each operating treatment facility under usual conditions will have a preferred range of respiration rates within which that plant will show its best continuing performance"
C. Summarize Significance of RR in Process Control	Use Slide 179.2/11.6.46 Slide 179.2/11.6.46 is a word slide which reads: "Activated Sludge Respiration Rate Interpretation 1. Increasing MLSS Rates - decreasing sludge stability

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	needs increased oxidative pressure to prevent overloading (decreased settleability) 2. Increasing Fed Sludge Rates - May approach limiting oxygenation capacities, decrease load to unit, use step feed, contact modification or chemical coagulation"
D. Summarize Use of Fed Sludge RR to Detect Toxic Loads	Use Slide 179.2/11.6.47 Slide 179.2/11.6.47 is a word slide which reads: "Activated Sludge Respiration Rate Interpretation A decrease in the respiration rate on fed sludge relative to an unfed endogenous rate indicates toxicity or unfavorable conditions. Needs time for regrowth"
E. Summarize Sludge Stabilization-Effluent Quality Relationships	Use Slide 179.2/11.6.48 Slide 179.2/11.6.48 is a word slide which reads: "Sludge Stabilization - Effluent Quality Relationships Under or over oxidized Sludges Lower Effluent Quality Some intermediate stabilization range Best Effluent Quality Relatable to respiration rate"
F. Use Remaining Time for Discussion	Use Slide 179.2/11.6.49 Slide 179.2/11.6.49 is a blank

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 6: Respiration Rate Control Procedures

Trainee Notebook Contents

Respiration Rate Control Procedures. T11.6.1

Sample Data Sheet for Respiration Rate Determination. T11.6.9

ACTIVATED SLUDGE PROCESS CONTROL TROUBLESHOOTING

Respiration Rate Control Procedures

I. ACTIVATED SLUDGE OPERATION

A. GOALS

1. Bacteria or "activated sludge" decompose (stabilize) organic material.

2. Bacteria form a satisfactory floc for effective separation and concentration of the biological solids in the settling unit.

B. ACHIEVEMENT OF GOALS

1. Decomposition requires that:

   a) Bacteria are available and utilize organics as a food source.

   b) Toxic or inhibitory materials are not present in high concentrations.

   c) Trace elements needed for complete metabolism are available.

   d) Sufficient oxygen is provided.

   e) Sufficient time is provided for biological reactions to occur.

2. Formation of floc requires that:

   a) Mechanical shearing is kept to a minimum.

   b) Quiescent area is provided for flocculation.

   c) The solids inventory is maintained in an acceptable range to properly stabilize the sludge solids

II. MEAN CELL RESIDENCE TIME

A. DEFINITION: The average number of days which an unit of activated sludge solids remains in the aeration tank -- final clarifier portion of the treatment plant.

B. CLASSIFICATION OF MEAN CELL RESIDENCE TIME (MCRT)

1. "Young sludge" -- bacterial cells are continuously surrounded by food and are dividing rapidly. Biological activity is high. Sludge is not very stable.

2. "Old sludge" -- bacterial cells have a very limited food supply and are utilizing their own cell mass for food. The cells are also receiving food from the breakdown or death of other cells. Biological activity is low. Sludge is very stable

3. "Acceptable sludge" -- bacterial cells have just enough food to maintain a good life style and the number of new cells being formed is about equal to the number of cells "approaching" death. Usually this is somewhere between 5-15 days mean cell residence time. Moderate level of biological activity and sludge is moderately stable.

III. RESPIRATION RATE

A. DEFINITION: The milligrams of oxygen utilized per hour by one gram of activated sludge solids. The "Respiration Rate" is sometimes called the specific oxygen uptake rate.

B. Apparatus.

1. D.O. Analyzer.
2. BOD Probe or Field Probe for D.O. Analyzer.
3. Magnetic Stirrer.
4. BOD Bottles or Erlenmeyer Flasks.
5. Sampling Bottles.
6. Graudated Cylinders.
7. Timer.

C. PROCEDURE FOR MEASUREMENT

1. Using BOD bottle and BOD probe

   a) Fill a one-liter jar half full with aeration tank effluent.

   b) Cap the jar and shake for one minute to saturate with dissolved oxygen.

   c) Fill a 300 ml BOD bottle with a portion of the sample.

   d) Place magnetic stirring bar in BOD bottle, place bottle on magnetic stirrer, and start stirring bar.

   e) Insert a self-stirring D.O. probe into the BOD bottle and take readings at the beginning and every minute for 10 minutes, or until D.O. is depleted.

   f) Tabulate the change in D.O. with respect to time (ΔD.O./min). This change should be the same for every minute.

   g) Calculate the oxygen uptake rate (OUR).

$$\text{OUR (mg. } O_2/l/hr) = \Delta\text{D.O./min} \times 60 \text{ min/hr}$$

h) Measure the mixed liquor suspended solids in grams/liter.

i) Calculate the Respiration Rate (RR)

$$RR\ (mg\ O_2/hr/g) = \frac{OUR\ (mg/l/hr)}{MLSS\ (g/l)}$$

2. Alternate Procedure

   a) Steps a and b above.

   b) Fill 500 ml Erlenmeyer flask with aerated sample.

   c) Step d above.

   d) Insert field probe into Erlenmeyer flask and record D.O. each minute for 10 minutes or until D.O. is depleted.

   e) Same as f-i above.

D. INTERPRETATION OF RESULTS*

1. Respiration Rate is high -- greater than 20 mg O_2/hr/gm.

   a) Sludge is too young.

   b) Aeration time too short.

   c) Food to microorganism ratio is too high.

   d) Sludge settles slowly and does not concentrate well.

   e) Effluent is high in BOD and suspended solids.

2. Respiration Rate is in the range 12-20 mg O_2/hr/gm.

   a) System is probably performing well and producing a good effluent.

3. Respiration Rate is low -- less than 12 mg O_2/hr/gm.

   a) In absence of inhibitory or toxic substances.

      1. Sludge is too old.

      2. Aeration time is too long.

      3. Food to microorganism ratio is too low.

      4. Sludge settles rapidly and concentrates quickly.

      5. Effluent is above optimum in BOD and suspended solids.

*Numerical values given are typical for conventional activated sludge systems. Optimum values must be determined for each plant individually.

b) Inhibitory or toxic substance is present.

E. RESPONSE TO RESULTS

1. If Respiration Rate is high:
    - a) Decrease sludge wasting.
    - b) Increase sludge aeration time if possible.
    - c) Increase the quantity of sludge solids in the aeration basin.
2. If Respiration Rate is low:
    - a) No toxic or inhibitory substances present.
        1. Increase sludge wasting.
        2. Decrease sludge aeration time if possible.
        3. Decrease the quantity of sludge solids in the aeration basin.
    - b) Toxic or inhibitory substances present.
3. If Respiration Rate is between 12 and 20 mg O_2/hr/gm
    - a) Keep doing what ever you're doing because it's right.
    - b) Sit down in your air conditioned lab for ten minutes and relax.

IV. LOAD FACTOR AND FEED ACCEPTABILITY

A. SAMPLE PREPARATION

1. Unfed sludge respiration rate sample.

$$\frac{\text{Volume return sludge used}}{\text{Volume final effluent used}} = \frac{\text{Return sludge flow rate}}{\text{Influent wastewater flow rate}}$$

2. Fed sludge respiration rate sample

$$\frac{\text{Volume return sludge used}}{\text{Volume influent wastewater used}} = \frac{\text{Return sludge flow rate}}{\text{Influent wastewater flow rate}}$$

3. Use 1000 ml of final effluent or influent wastewater, add required amount of return sludge, mix thoroughly and fill container used in the respiration rate test with the mixture.

B. Unfed sludge respiration rate

1. Mix sample of final clarifier effluent and return sludge as determined by calculation in A.

2. Perform oxygen uptake test.

3. Test results (unfed sludge respiration rate) indicate condition of sludge entering aeration basin after previous aeration and residence in clarifier.

4. Interpretation.

   a) Unfed rate indicates stability of the sludge mass following previous aeration and settling.

      1. Will follow the load during the day and week.

      2. 0.3 - 0.7 mg DO/1/min. "normal" at approximately 2500 mg/1 MLSS.

   b) Low Unfed sludge respiration rate.

      1. Indicates starved, overoxidized sludge.

      2. Fast settling rate.

      3. Pin floc or ashing possible.

      4. Common to extended air systems - old sludge.

      5. Try to decrease oxidative pressures.

         (a) Increase wasting to decrease solids inventory.

         (b) Decrease aeration detention time.

         (c) Decrease quantity of sludge under aeration.

         (d) Go to conventional mode if sludge reaeration is being used.

   C) High unfed sludge respiration rate.

      1. Underoxidized sludge.

      2. May go septic in clarifier.

      3. Poor settleability and sludge compaction.

      4. Try to increase oxidative pressures.

         (a) Decrease wasting to increase solids inventory.

         (b) Increase aeration detention time.

         (c) Increase quantity of sludge under aeration.

         (d) Use sludge reaeration.

C. Fed sludge respiration rate

1. Mix raw sewage or primary effluent with return sludge in ratio determined by calculation in A.

2. Perform oxygen uptake test.

3. Test results (fed sludge respiration rate) indicates combined effects of feed and sludge. The ΔDO should be 2 to 4 times that of the unfed sludge.

4. Interpretation (Fed Rate)

   a) Fed sludge respiration rates.

      1. Follows availability and conc. of feed.

      2. Change more than unfed rates.

      3. Provide time to anticipate influent changes and make corrections.

   b) After feeding, the sludge respiration rate is expected to increase above the unfed sludge respiration rate.

      1. May exceed oxygen transfer capacity of aeration equipment.

         (a) Most aeration tanks with good O_2 transfer will handle O_2 uptake rates of 2.0 - 2.5 mg O_2/liter/min.

         (b) Step feed to distribute load.

         (c) Improve tank mixing, modify aerator placement.

         (d) Taper air supply.

D. Load factor (LF)

1. Ratio of fed sludge activity to unfed sludge activity.

2. $$LF = \frac{\text{Fed Sludge Respiration Rate}}{\text{Unfed Sludge Respiration Rate}}$$

3. Indicates activity before and after feeding.

4. Good sludge and acceptable feed increases oxygen uptake - load factor >1.

5. Other cases.

   a) $LF < 1$, inhibitory or toxic load.

   b) $1 < LF < 2$, dilute or stable load.

   c) $2 < LF < 5$, acceptable loading.

   d) $LF > 5$, possible oxygen supply problems.

970

E. Feed acceptability

1. Toxic or inhibitory substances will depress fed rate relative to unfed sludge rate (load factor < 1).

    a) Treatment will suffer.

    b) Try coagulation or powered activated carbon treatment.

    c) If toxic loads are repeated, identify problem areas along collection system.

    d) If feed is suspect, check by using an acceptable feed (such as dextrose or sucrose) to determine if low activity is due to feed or sludge.

2. Small increase in LF can be due to dilute feed, poor quality feed, sick sludge, or unfavorable conditions.

3. Other common problems.

    a) Most reflected in observations (color, foam, settleability, etc.).

    b) Many problems can be detected earlier with respiration rate data.

4. Typical problem - organic load to plant increases significantly.

    a) Load factor increases significantly (fed sludge respiration rate increases).

    b) Low D.O. at head end of tank.

    c) Increase in sludge blanket depth (slow settling sludge).

    d) If load persists (through several sludge cycles) unfed rate will continue to increase - sludge will continue to pile up in clarifier as settling rate continues to decrease.

    e) Increasing RSF will add to clarifier hydraulic load, may cause solids washout, will decrease aeration detention time. In short, increasing RSF probably causes problem to get worse.

    f) Wasting decreases solids inventory and reduces oxidative pressure further.

    g) Probable solutions:

        1. Decrease wasting to build solids inventory.

        2. Reduce RSF to increase aeration detention time.

3. Switch to sludge reaeration mode of operation.

4. Taper air to aeration basin.

V. STABILIZATION TESTS

A. Reflect sludge activity during aeration cycle.

B. Before feeding, the uptake rate is equal to the unfed sludge uptake rate.

C. After feeding, the uptake rate (Δ DO/min.) usually rises, then decreases as the mixture is stabilized.

D. As stabilization proceeds.

1. Oxygen uptake rate decreases.

2. Floculation tendencies increase.

3. Settling rate increases.

4. Solids - liquid separation improves until over stabilization occurs then solids - liquid separation may deteriorate.

E. There is some intermediate stabilization range that gives the best effluent quality.

F. Test Procedure.

1. Determine unfed sludge oxygen uptake rate.

2. Mix and aerate R.S. and wastewater feed in a small tank or bucket (in same proportions as in aeration basin).

3. At t = 0, draw off sample for uptake test (pour back into tank after determining ΔD.O.).
4. Repeat (3) every 10 or 15 minutes until the uptake rate approaches the initial unfed rate.

5. Plot oxygen uptake rate (Δ DO/min.) vs. time (min.).

G. Results permit operator to determine.

1. If aeration time is adequate.

2. Excessive oxygen demands.

3. Effect of new load, etc.

H. Stabilization curve only developed a few times per year

1. New industry on stream.

2. Season changes.

3. Changes in loading.

SAMPLE DATA SHEET
FOR
RESPIRATION RATE DETERMINATION

PLANT NAME ________________________________ OPERATOR ____________________
SAMPLE LOCATION ____
DATE AND TIME OF SAMPLING ____
TIME OF R.R. TEST ____
SUSPENDED SOLIDS CONCENTRATION OF SAMPLE ____________________ mg/l
TEMPERATURE OF SAMPLE ____

TIME	ΔD.O.	D.O.
0 min.		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

$$\Delta D.O./hr = \overset{\Delta D.O./min.}{\underline{\qquad\qquad}} \times 60\ min./hr$$

$$\Delta D.O./hr = \underline{\qquad\qquad}$$

$$\text{RESPIRATION RATE} = \frac{\Delta D.O./hr}{MLSS} \times \frac{1000\ mg}{g} = \frac{(\overset{\Delta D.O./hr}{\underline{\qquad\qquad}})}{(\underset{MLSS}{\qquad\qquad})} \times 1000$$

RESPIRATION RATE = ____________________ mg O_2/hr/g

TROUBLESHOOTING O & M PROBLEMS IN
WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 7: Identifying Problem Causes in Activated Sludge

Lesson 7 of 14 lessons Recommended Time: 90 minutes

Purpose: Four major process control decision making tools, F/M, MCRT, Sludge Settleability and RR, are used in activated sludge process control, evaluation and troubleshooting. Many operators and troubleshooters routinely use only one or two of these tools and, therefore, attempt to control the process based on limited or partial information. The problem solving exercise in this lesson requires the trainee to solve a generalized process control problem, identify the possible causes of the problem, describe how the actual problem cause would be determined and recommend corrective actions for each possible cause identified. The exercise forces the trainee to look at the interrelationships between the various process control decision making tools.

Trainee Entry Level Behavior: Trainees should have achieved the learning objectives specified for Unit 11, Lessons 1 - 6 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. Given design information about a model activated sludge treatment plant, information that a change has occurred in one of the parameters F/M, MCRT, Sludge Settleability or RR and using *Trainee Notebook* references and class notes, list all possible causes of the observed change in the process control parameter, describe the expected change in other process control parameters which would confirm each possible cause as the most likely cause and list the recommended process control responses to each possible cause of the observed change in the process control parameters.

2. When called upon by the instructor, report his/her findings for the given conditions and justify his/her recommendations for process control responses.

3. Using class notes and *Trainee Notebook* references, explain why it is necessary to consider concurrent changes in at least four parameters, F/M, MCRT, Sludge Settleability and RR, when evaluating an activated sludge system to identify problems and their probable causes.

Instructional Approach: Trainee problem solving in work groups of four trainees and discussion of trainee findings.

Lesson Schedule: The 90 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 10 minutes	Instructor Introduces the Problem
10 - 45 minutes	Trainee Problem Solving
45 - 85 minutes	Trainees Report Findings
85 - 90 minutes	Instructor Summarizes Lesson

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, page T11.7.1, "Activated Sludge Process Troubleshooting, Problem Identification and Process Control Response - Problem Statement."

2. *Trainee Notebook*, page T11.7.4, "Activated Sludge Process Troubleshooting, Problem Identification and Process Control Response - Instructions for Completing Worksheet."

3. *Trainee Notebook*, page T11.7.5 - T11.7.12, "Activated Sludge Process Troubleshooting, Problem Identification and Process Control Response-Worksheets

4. All trainee references and *Trainee Notebook* materials used in Unit 11, Lessons 1 - 6.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 11, Lesson 7, pages 11.7.1 - 11.7.9.

2. *Instructor Notebook*, pages H11.7.1 - H11.7.37, "Activated Sludge Process Troubleshooting, Problem Identification and Process Control Response" (to be reproduced and distributed to trainees at the conclusion of the lesson.)

Instructor Materials Recommended for Development: None

Additional Instructor References: As specified in Unit 11, Lessons 1 - 6.

Classroom Set-Up:

1. Lesson Introduction: As specified in Unit 11, Lesson 1.

2. Trainee Problem Solving: One separate breakout room for each trainee workgroup so that individual work groups have a private quiet area in which to meet and discuss the work group's assigned problem

3. Trainees Report Findings: As specified in Unit 11, Lesson 1.

LESSON OUTLINE

I. Instructor Introduces the Problem (10 minutes)

A. Introduction

1. Have discussed several process control and evaluation tools and their significance.
    - a. F/M
    - b. MCRT
    - c. Sludge Settleability
    - d. RR

2. Now its time to apply what has been covered to activated sludge process troubleshooting.

3. Do this by developing a series of process control and troubleshooting guides

B. Have class read Problem Situation

1. Refer class to *Trainee Notebook*, page T11.7.1-T11.7.2 for a statement of the situation. *Trainee Notebook* pages T11.7.1 - T11.7.11 are included in the *Instructor Notebook*.

2. Emphasize that the situation is designed to provide a maximum of process control flexibility which is available to the operator and troubleshooter. The specifics of plant design are really immaterial to this problem.

3. The objective is to provide specific guidelines to the operator on how to correctly use the available process flexibility to achieve and maintain good effluent quality.

KEY POINTS & INSTRUCTOR GUIDE

Refer class to *Trainee Notebook*, pages T11.7.1-T11.7.11 for a statement of the problem, instructions and worksheets.

LESSON OUTLINE

C. Instructions for Completing the Problem Worksheets

1. Refer class to *Trainee Notebook*, pages T11.7.4 - T11.7.11, "Activated Sludge Process Troubleshooting, Problem Identification and Process Control Response Worksheets" and page T11.7.3 for "Instructions for Completing Worksheets" These pages are included in the *Instructor Notebook.*

2. Review instructions and worksheets with the class.

D. Make Worksheet Assignments

1. Assign worksheets to trainee workgroups for completion.
    - a. Trainee Group 1, page T11.7.4, F/M Increasing.
    - b. Trainee Group 2, page T11.7.5, F/M Decreasing.
    - c. Trainee Group 3, page T11.7.6, MCRT Increasing.
    - d. Trainee Group 4, page T11.7.7, MCRT Decreasing.
    - e. Trainee Group 5, page T11.7.8, MLSS RR Increasing.
    - f. Trainee Group 6, page T11.7.9, MLSS RR Decreasing.
    - g. Trainee Group 7, page T11.7.10, Settling Rate Increasing.
    - h. Trainee Group 8, page T11.7.11, Settling Rate Decreasing.

KEY POINTS & INSTRUCTOR GUIDE

Instructor should refer to pages H11.7.1 -H11.7.37 which are the completed worksheets to gain a better understanding of the expected trainee responses to the worksheet exercise

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

2. Each work group should complete its assigned worksheet by working as a team. Stress the importance of discussion within the group.

3. Work groups will have about 35 minutes to complete their assigned worksheets.

4. Inform work groups that when the class reconvenes, each work group will report its findings to the class and justify its recommendations.

E. Direct Work Groups to Their Work Areas

1. Separate work areas, preferably separate rooms, should be provided for each work group so that the group may freely discuss the assigned problem and develop a group concensus solution without interfering with the work of another group.

2. Assign a work area to each group and give directions for finding the assigned work area.

F. Answer any questions about the exercise before sending groups to their work areas.

II. Trainee Problem Solving (35 minutes)

A. Circulate among work groups to monitor progress and answer questions.

B. Review each work group's product periodically and redirect their efforts as necessary.

C. If a group completes the assigned work sheet early, assign a second work sheet to the group.

D. Periodically inform groups of time remaining

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
E. Reconvene groups in the main classroom at the end of the 35 minute work period.	
III. Trainees Report Findings (40 minutes)	
A. Reconvene class in main classroom.	
B. Have work groups report their findings.	
1. Call on groups sequentially, beginning with Group 1, to report findings (allocate about 8 minutes per group).	
a. Group 1 - F/M Increasing	School Solutions Refer to pages H11.7.1-H11.7.7
b. Group 2 - F/M Decreasing	Refer to pages H11.7.8-H11.7.13
c. Group 3 - MCRT Increasing	Refer to pages H11.7.14-H11.7.15
d. Group 4 - MCRT Decreasing	Refer to pages H11.7.16-H11.7.19
e. Group 5 - MLSS RR Increasing	Refer to pages H11.7.20-H11.7.23
f. Group 6 - MLSS RR Decreasing	Refer to pages H11.7.24-H11.7.28
h. Group 7 - Settling Rate Increasing	Refer to pages H11.7.29-H11.7.33
i. Group 8 - Settling Rate Decreasing	Refer to pages H11.7.34-H11.7.37
2. Encourage class discussion as each possible cause is presented.	
3. Using the suggested solutions on pages H11.7.1-H11.7.37 , challenge groups to justify their recommendations as appropriate.	
4. Note that there is overlap and commonality between the correct responses for the eight observed conditions given in the worksheets, e.g., a rising F/M will cause a decreasing settling rate.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
and an increasing MLSS RR which could be associated with a decreasing MCRT. Therefore, several groups should identify the same probable causes, confirmation observations and control responses. Use this information to draw several groups into the discussion	
c. Distribute solutions to the class after discussion is complete.	Reproduce pages H11.7.1 - H11.7.37 in sufficient quantity to distribute to the class.
IV. Instructor Summarizes Lesson (5 minutes)	
A. Using one solution sheet, page T11.7.4, the F/M increasing case, point out that there were many things which could have caused this observation. Point out that the correct process control response was different for each possible cause of the problem although several other control responses could be made to reverse the observed increase in F/M if this were the only information available to the operator and troubleshooter.	
B. Point out that by looking at the four control parameters, F/M, MCRT, Sludge Settleability and MLSS RR, together it is fairly easy to eliminate several possible causes and narrow the list to the one most likely cause.	
C. After identifying the cause of the problem, a correct process control response decision can be made.	
D. Emphasize the importance of looking at all available information about the process before making a process control decision and changing process control variables. Incorrect control responses can be made if only one parameter is considered. This may cause more problems that it solves.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
E. Recommend that routine monitoring of F/M, MCRT, Sludge Settleability and process respiration rates be considered for all activated sludge plants. If it is practical (personnel and dollar resources available) to institute a comprehensive process control management system, the process can be controlled to produce good effluents consistently.	

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 7: Identifying Problem Causes in Activated Sludge

Trainee Notebook Contents

Problem Identification and Process Control Response - Problem Statement T11.7.1

Flow Schematic for Use in Problem Solving T11.7.3

Problem Identification and Process Control Response - Instructions for Completing Worksheet. T11.7.4

Problem Identification and Process Control Response - Worksheets . . . . T11.7.[illegible]

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

Problem Statement

While attending a local operator association meeting, you are introduced to John Schmitt, superintendent at a new 10 MGD step feed activated sludge plant. John has heard that you are an expert in activated sludge process control and asks you to help him solve recurrent process control problems which have occurred at the new plant. The plant has been in operation about a year but has never consistently produced a good effluent.

John informs you that he was superintendent at the city's old trickling filter plant which was replaced by the new activated sludge plant about a year ago. John confesses that he knows very little about activated sludge treatment and process control. Everything he knows about process control in the plant he got from the O & M manual which was prepared by the design firm as the new plant was constructed. Because he knows little about activated sludge, John has mechanically followed the process control procedure outlined in the O & M manual but has never been able to get the plant to perform properly.

The plant deisgn flow is 10 MGD. There are separate storm water and sewage collection systems. The raw sewage is pumped to the plant headworks from a large lift station which is equipped with one variable speed 5000 gpm, one constant speed 5000 gpm and one constant speed 3000 gpm raw sewage pumps activated by level controllers in the wet well. Preliminary treatment consists of bar screening, comminution, grit removal and flow measurement. The pretreated waste is fed to two circular primary clarifiers. The primary effluent from the two tanks discharges to a common channel which feeds the aeration basin. The aeration basin has step feed capability at the quadrant points in the four pass plug flow aeration tank. Mixed liquor is distributed to two circular final clarifiers. The final clarifier effluent is chlorinated before discharging to the river. The underflow from the two clarifiers discharges to a common return sludge wet well. There are two variable speed 5000 gpm return sludge pumps. All return sludge discharges to the first quadrant of the aeration basin. Return sludge flow is metered, and the return sludge flow can be varied from 1400 to 10,000 gpm. Waste activated sludge is pumped from the return sludge wet well to the primary clarifiers. The waste sludge pump is a 1500 gpm constant speed pump activated by a time clock mechanism. There have been no problems in solids handling.

John informs you that there are several industries in town which discharge to the plant and sometimes cause relatively large variations in hydraulic and organic load to the plant. The average daily flow to the plant is 9.0 MGD.

John always operates the plant in the conventional treatment mode with all influent wastewater and return sludge entering the first quadrant of the aeration basin. John normally operates with a constant return sludge flow rate of about 6 MGD and only varies the return rate if the sludge blanket in the final clarifier begins to fall or rise. A constant volume of sludge is wasted each day because the waste rate has not been changed from the wasting rate set by the engineer during plant start-up.

John tells you that plant performance is erratic. Sometimes the sludge bulks and washes out of the final clarifiers. Sometimes the sludge separates very well in the final clarifiers but leaves a turbid ashy type effluent. Sometimes the plant produces a good effluent but not very often. John is upset because he had been told that this plant would produce an excellent effluent and consistently meet his discharge permit requirement of 20 mg/l BOD and 20 mg/l TSS. But he can't seem to make the thing work.

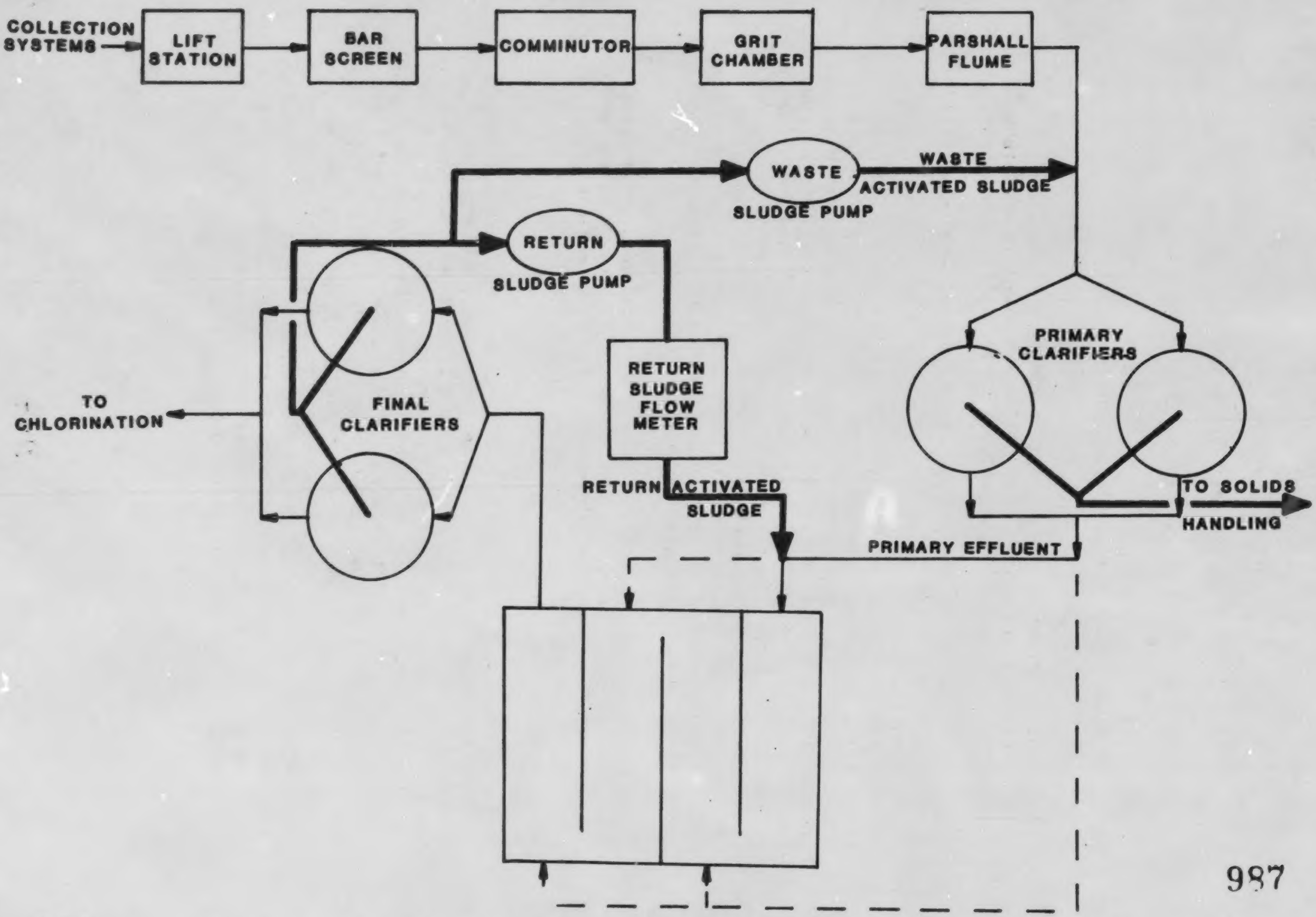
John tells you that he has a well equipped laboratory and a good lab technician who's running all the tests specified in the O & M manual and the permit. John knows that these test results should be used in controlling the plant but he doesn't know what the test results mean or how to use them.

John wants you to teach him how to make the plant work. You decide to accept the job.

To accomplish the task, you decide to develop a series of process control and troubleshooting charts as work aids which John can use to help him interpret his process control laboratory data.

You will use the attached worksheets, pages T11.7.5 - T11.7.12 to develop the process control and troubleshooting charts. You and the members of your workgroup will be assigned one worksheet to complete. After you have completed your assigned worksheet, you will present the information from your worksheet to the class.

T 11.7.3



FLOW SCHEMATIC FOR USE IN PROBLEM SOLVING

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

Instructions for Completing Worksheet

1. Prepare the worksheet in the context of the problem statement, i.e., a very flexible plant design which can accommodate many different process control adjustments in response to observed process conditions.

2. A change is observed in one process control parameter as specified at the top of the worksheet.

3. *Possible Causes of Observed Condition.* Possible Cause: List all things which could have occurred in the system to cause the change observed in the monitored parameter. Be as specific as possible. For example, if one possible cause for the observed condition is a change in applied load, specify the ways in which the load change could occur. Applied BOD load could increase because (a) the influent BOD concentration increases with flow remaining constant, (b) the influent flow rate increases with the BOD concentration remaining constant, (c) both flow rate and BOD concentration increase, (d) an internal plant recycle stream is returned to the aeration basin, etc.

   Observations and Data to Confirm Cause: What additional observations and tests would you perform to confirm this as the cause of the problem and what result would you expect to see. For each possible cause, include the expected change in F/M, MCRT, Sludge Settleability and MLSS RR as your minimum entry in this column.

4. *Process Control Response to Observed Condition.* For each possible cause of the observed condition, enter the correct process control response. Process control responses should be considered as immediate or temporary (things to do right now to solve an immediate problem) and long term (things to be done which will correct the problem and prevent possible recurrence of the problem). For example, suppose the sludge settling rate decreases because of organic overload and the final clarifier sludge blanket becomes very high and solids wash-out from the clarifier in imminent. Then an immediate response may be to lower the sludge blanket by increasing return rate temporarily to prevent solids wash-out, but the long term solution to correct the problem may be to reduce return sludge rate and increase solids inventory. Be as exact and complete as possible in listing process control responses.

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

Worksheet

PARAMETER MONITORED: F/M

CONDITION OBSERVED: F/M Increasing

POSSIBLE CAUSES OF OBSERVED CONDITION:

Possible Cause	Observations and Data to Confirm Cause
1.	
2.	
3.	
4.	
5.	

PROCESS CONTROL RESPONSE TO OBSERVED CONDITION:

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
1		
2		
3		
4		
5		

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

Worksheet

PARAMETER MONITORED: F/M CONDITION OBSERVED: F/M Decreasing

POSSIBLE CAUSES OF OBSERVED CONDITION:

Possible Causes	Observations and Data to Confirm Cause
1.	
2.	
3.	
4.	
5.	

PROCESS CONTROL RESPONSE TO OBSERVED CONDITION:

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
1		
2		
3		
4		
5		

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

Worksheet

PARAMETER MONITORED: MCRT CONDITION OBSERVED: MCRT Increasing

POSSIBLE CAUSES OF OBSERVED CONDITION:

Possible Causes	Observations and Data to Confirm Cause
1.	
2.	
3.	
4.	
5.	

PROCESS CONTROL RESPONSE TO OBSERVED CONDITION:

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
1		
2		
3		
4		
5		

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

Worksheet

PARAMETER MONITORED: MCRT CONDITION OBSERVED: MCRT Decreasing

POSSIBLE CAUSES OF OBSERVED CONDITION:

Possible Causes	Observations and Data to Confirm Cause
1.	
2.	
3.	
4.	
5.	

PROCESS CONTROL RESPONSE TO OBSERVED CONDITION:

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
1		
2		
3		
4		
5		

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

Worksheet

PARAMETER MONITORED: MLSS RR *CONDITION OBSERVED:* MLSS RR Increasing

POSSIBLE CAUSES OF OBSERVED CONDITION:

Possible Causes	Observations and Data to Confirm Cause
1.	
2.	
3.	
4.	
5.	

PROCESS CONTROL RESPONSE TO OBSERVED CONDITION:

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
1		
2		
3		
4		
5		

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

Worksheet

PARAMETER MONITORED: MLSS RR *CONDITION OBSERVED:* MLSS RR Decreasing

POSSIBLE CAUSE OF OBSERVED CONDITION:

Possible Causes	Observations and Data to Confirm Cause
1.	
2.	
3.	
4.	
5.	

PROCESS CONTROL RESPONSE TO OBSERVED CONDITION:

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
1		
2		
3		
4		
5		

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

Worksheet

PARAMETER MONITORED: Sludge Settleability

CONDITION OBSERVED: Settling Rate Increasing

POSSIBLE CAUSE OF OBSERVED CONDITION:

Possible Causes	Observations and Data to Confirm Cause
1.	
2.	
3.	
4.	
5.	

PROCESS CONTROL RESPONSE TO OBSERVED CONDITION:

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
1		
2		
3		
4		
5		

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

Worksheet

PARAMETER MONITORED: Sludge Settleability *CONDITION OBSERVED:* Settling Rate Decreasing

POSSIBLE CAUSE OF OBSERVED CONDITION:

Possible Causes	Observations and Data to Confirm Cause
1.	
2.	
3.	
4.	
5.	

PROCESS CONTROL RESPONSE TO OBSERVED CONDITION:

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
1		
2		
3		
4		
5		

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 7: Identifying Problem Causes in Activated Sludge

Instructor Handout Contents

Problem Identification and Process Control
Response - Answer Sheets . . . . H11.7.1 - H11.7.37

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

PARAMETER MONITORED: F/M

OBSERVED CONDITION: F/M Increasing

POSSIBLE CAUSES OF OBSERVED CONDITION:

Possible Causes	Observations and Data to Confirm Cause
1. Increased organic load caused by increased influent BOD concentration with little change in influent flow rate	1. Settling rate - decreasing MLSS RR - increasing MCRT - constant or slowly increasing Solids Inventory - constant or slowly increasing Fed Sludge RR - increasing Influent Flow Rate - about the same Aeration Basin D.O. - decreasing
2. Increased organic load caused by increased influent BOD concentration with a decrease in influent flow rate	2. Settling rate - decreasing or no change MLSS RR - increasing or no change MCRT - constant or slowly increasing Solids Inventory - constant or slowly increasing Fed Sludge RR - increasing Influent Flow Rate - decreasing Aeration Basin D.O. - decreasing or about the same
3. Increased organic load caused by increase in influent flow rate with little change in influent BOD concentration	3. Settling Rate - usually decreasing MLSS RR - increasing MCRT - constant or slowly increasing Solids Inventory - constant or slowly increasing Fed Sludge RR - about the same Influent Flow Rate - increasing Aeration Basin D.O. - decreasing
4. Increased organic load caused by increase in influent flow rate with a decrease in influent BOD concentration	4. Settling Rate - decreasing or no change MLSS RR - increasing or no change MCRT - Constant or slowly increasing Solids Inventory - constant or slowly increasing Fed Sludge RR - decreasing Influent Flow Rate - increasing Aeration Basin D.O. - decreasing or about the same

F/M Increasing (Continued)

Possible Causes	Observations and Data to Confirm Cause
5. Increased organic load caused by increase in both influent BOD and influent flow rate	5. Settling Rate - decreasing MLSS RR - increasing MCRT - constant or slowly increasing Solids Inventory - constant or slowly increasing Fed Sludge RR - increasing Influent Flow Rate - increasing Aeration Basin D.O. - decreasing
6. Increased organic load caused by internal plant recycles	6. Settling Rate - decreasing MLSS RR - increasing MCRT - constant or slowly increasing Solids Inventory - constant or slowly increasing Fed Sludge RR - about the same if sample collected before recycle stream enters the aeration system - increasing if sample collected after recycle stream enters the aeration system Influent Flow Rate - about the same Aeration Basin D.O. - decreasing
7. Decrease in solids inventory caused by excessive deliberate wasting	7. Settling Rate - decreasing MLSS RR - increasing MCRT - decreasing Solids Inventory - decreasing Fed Sludge RR - about the same Influent Flow Rate - about the same Aeration Basin D.O. - increasing or about the same
8. Decrease in solids inventory caused by excessive effluent suspended solids	8. Settling Rate - decreasing MLSS RR - increasing MCRT - decreasing Solids Inventory - decreasing Fed Sludge RR - about the same Influent Flow Rate - about the same Aeration Basin D.O. - increasing or about the same
9. Nitrification occurring in BOD test used to measure applied load	9. Settling Rate - no change MLSS RR - no change MCRT - no change Solids Inventory - no change Fed Sludge RR - no change or increasing Influent Flow Rate - about the same Aeration Basin D.O. - about the same

F/M Increasing (Continued)

PROCESS CONTROL RESPONSE TO OBSERVED CONDITIONS:

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
1	a. Check final clarifier sludge blanket depth. 1) If the blanket is rising rapidly with possibility of solids washout, then temporarily increase return rate or waste rate to lower sludge blanket. Reduce return or waste rate as soon as blanket can be retained in final clarifier. CAUTION: Increased hydraulic load on clarifier may cause solids washout. This action may cause slow sludge settling problem to get worse before long range corrective actions affect process. This temporary response is a calculated risk! 2) If the sludge blanket is not out of control, implement long term corrective actions b. Check aeration basin D.O. If D.O. is less than 1 mg/l, increase air supply	a. When sludge blanket can be retained in final clarifier, reduce return sludge flow rate-concentrates return sludge and increases aeration detention time. b. Reduce deliberate wasting to increase solids inventory and sludge aeration time. Continue to monitor F/M, sludge settleability and MLSS RR and balance system to new conditions of solids inventory and MCRT to treat increased load. c. If a and b don't work, then 1) Increase aeration detention time by placing additional aeration basins into service. 2) Increase sludge detention time by converting to sludge reaeration operating mode
2	Same as possible cause 1 responses	a. If settling rate and MLSS RR are not changing, continue current operating practices but monitor settleability and MLSS RR frequently and respond to any changes which occur because of increased organic load. b. If settling rate is decreasing and MLSS RR is increasing, then implement corrective actions listed for possible cause 1.

F/M Increasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Actions
3	Same as possible cause 1 responses	Same as possible cause 1 responses
4	Same as possible cause 1 responses	Same as possible cause 2 responses
5	Same as possible cause 1 responses	Same as possible cause 1 responses. Need to use additional aeration volume or sludge reaeration to handle new load is more likely for these influent load conditions.
6	a. Same as possible cause 1 responses	a. Same as possible cause 1 responses
	b. Identify source of internal recycle and modify operations creating the internal recycle to eliminate or reduce the recycle, if possible	b. If internal recycles cause serious problems which interfere with treatment of influent wastewater, the recycles cannot be eliminated and the aeration system cannot be controlled by responses in a, then 1) Pre-treat recycle streams before returning to aeration system; 2) Provide means to equalize recycle loads and bleed them into aeration system; 3) Pre-aerate recycle streams before returning to aeration system; 4) Consider and evaluate use of chemical additives such as coagulants and coagulant aids in aeration system to maintain process integrity.
7	Same as possible cause 1 responses	a. Decrease waste activated sludge to increase solids inventory. Monitor F/M and MCRT and readjust wasting rate when parameters are in optimum range.

F/M Increasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
		b. Decrease return activated sludge flow rate to concentrate return and increase aeration basin detention time
		c. If a and b are not effective
		1) Increase aeration volume in use
		2) Use sludge reaeration mode of operation
8	a. Same as possible cause 1 responses	a. Same as possible cause 7 responses
	b. Check and evaluate final clarifier operation and design for possible problems	b. Correct final clarifier deficiencies
	1) Sludge collection, return or wasting systems not operating properly	
	a) Rake or collector drive mechanism broken or shut off because of torque overload	1a) Repair or reset
	b) Broken chains	1b) Repair or replace
	c) Missing flights or scrappers	1c) Repair
	d) Plugged collectors or pumps	1d) Unplug collectors or pumps
	e) Pumps not operating	1e) Repair or reset pumps
	2) Hydraulic overload	2a) Put additional clarifiers in service, if possible
		2b) Reduce hydraulic load to clarifier, if possible

F/M Increasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
	3) Solids overload	3a) Put additional clarifiers in service
		3b) Reduce solids load to clarifier, if possible
		3c) Take actions to produce faster settling solids (possible cause 7 responses)
	4) Improperly maintained clarifier weirs	4) Check weirs for level and level if necessary
	5) Unequal load distribution to multiple clarifiers	5a) Check weirs to verify that all clarifiers have same weir elevation. Adjust as needed
		5b) Check inlet and effluent structures for obstructions - remove obstructions
		5c) Check and adjust flow distribution system
	6) Improperly designed clarifier	
	a) High velocity currents at weirs	6a1) Check adequacy of total weir length. Add weirs if needed
		2) Block excess weirs which may cause localized velocity currents
		3) If velocity currents caused by weir placement too close to wall, move weirs away from wall
	b) Short circuiting	6b1) Check and adjust weirs
		2) Check adequacy of inlet target baffles and skirts. Correct target baffles and skirt deficiencies.

F/M Increasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
		3) If inlet velocities are excessive, provide mechanism to dampen inlet velocities
		4) Check for thermal stratification in clarifier. Eliminate cause of thermal stratification
9		a. Continue operation using current practices if process is performing well and there are no other problems
		b. Check, evaluate and correct BOD test procedure. Most likely cause is high nitrifier population in seed organisms used in BOD test
		1) Change seed
		2) Inhibit nitrification in BOD test using alternate procedure
		NOTE: This problem frequently occurs in effluent BOD determination also
		c. Nitrification in influent BOD test may be desirable, and hence, this is not a problem.

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

PARAMETER MONITORED: F/M

CONDITION OBSERVED: F/M Decreasing

POSSIBLE CAUSE OF OBSERVED CONDITION:

Possible Cause	Observations and Data to Confirm Cause
1. Decreased organic load caused by decreased influent BOD concentration with little change in influent flow rate	1. Settling Rate - increasing MLSS RR - decreasing MCRT - constant or slowly decreasing Solids Inventory - constant or slowly decreasing Fed Sludge Rate - decreasing Influent Flow Rate - about the same Aeration Basin D.O. - increasing
2. Decreased organic load caused by a decrease in influent BOD concentration with an increase in influent flow rate	2. Settling Rate - increasing, decreasing or no change MLSS RR - decreasing, increasing or no change MCRT - constant or slowly decreasing Solids Inventory - constant or slowly decreasing Fed Sludge Rate - decreasing Influent Flow Rate - increasing Aeration Basin D.O. - increasing or no change
3. Decreased organic load caused by a decrease in both influent BOD concentration and flow rate	3. Settling Rate - usually increasing MLSS RR - decreasing MCRT - constant or slowly decreasing Solids Inventory - constant or slowly decreasing Fed Sludge RR - decreasing Influent Flow Rate - decreasing Aeration Basin D.O. - increasing
4. Decreased organic load caused by a decrease in influent flow rate with little or no change in influent BOD concentration	4. Settling Rate - increasing MLSS RR - decreasing MCRT - constant or slowly decreasing Solids Inventory - constant or slowly decreasing Fed Sludge RR - about the same Influent Flow Rate - decreasing Aeration Basin D.O. - increasing

F/M Decreasing (Continued)

Possible Cause	Observations and Data to Confirm Cause
5. Decreased organic load caused by a decrease in influent flow rate with an increase in influent BOD concentration	5. Settling Rate - increasing MLSS RR - decreasing MCRT - constant or slowly decreasing Solids Inventory - constant or slowly decreasing Fed Sludge RR - increasing Influent Flow Rate - decreasing Aeration Basin D.O. - increasing
6. Increase in solids inventory caused by insufficient deliberate wasting	6. Settling Rate - increasing MLSS RR - decreasing MCRT - increasing Solids Inventory - increasing Fed Sludge RR - about the same Influent Flow Rate - about the same Aeration Basin D.O. - about the same or decreasing
7. Apparent decrease in applied organic load caused by presence of toxic or inhibitory substances	7. Settling Rate - decreasing, possible deflocculation and turbid effluent MLSS RR - decreasing MCRT - constant or decreasing Solids Inventory - constant or decreasing Fed Sludge RR - Less than unfed sludge RR Influent Flow Rate - about the same Aeration Basin D.O. - increasing Microscopic Examination - inactive or encysted protozoans
8. Apparent decrease in applied load caused by nutrient deficient influent	8. Settling Rate - decreasing, possible deflocculation and turbid effluent MLSS RR - decreasing MCRT - constant or decreasing Solids Inventory - constant or decreasing Fed Sludge RR - lower than normal Influent Flow Rate - about the same Aeration Basin D.O. - increasing
9. Apparent decrease in applied load caused by change in nature of organic load to slowly metabolized organics	9. Settling Rate - decreasing or no change MLSS RR - increase or no change MCRT - constant Solids Inventory - constant Fed Sludge RR - lower than expected Influent Flow Rate - about the same Aeration Basin D.O.- increasing or no change

F/M Decreasing (Continued)

PROCESS CONTROL RESPONSE TO OBSERVED CONDITION:

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
1	Monitor aeration basin D.O. and decrease air supply rate if warranted	a. Increase return sludge flow rate to decrease aeration detention time and return a more dilute sludge
		b. Increase wasting to decrease solids inventory and establish new operating ranges for F/M and MCRT to treat decreased load
		c. If a and b don't work and you're operating in sludge reaeration mode, move toward conventional mode to reduce oxidation pressures
2	Same as response to possible cause 1	a. If settling rate is increasing, and MLSS RR is decreasing, then 1) Increase return sludge flow rate 2) Increase wasting if trends in settling rate and MLSS RR cannot be reversed with return rate control 3) If 1 and 2 don't work, move from sludge reaeration mode of operation toward conventional mode of operation
		b. If settling rate and respiration rate don't change, continue present operating practices
		c. If settling rate is decreasing and MLSS RR is increasing, then 1) Reduce return sludge flow rate 2) Decrease wasting if trends in settling rate and MLSS RR cannot be reversed with return rate control because effect is caused by an inadequate solids inventory

F/M Decreasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
		3) If 1 and 2 don't work, move from conventional operating mode to sludge reaeration operating mode
3	Same as response to possible cause 1	Same as response to possible cause 1
4	Same as response to possible cause 1	Same as response to possible cause 1
5	Same as response to possible cause 1	Same as response to possible cause 1
6	If problem is extreme (i.e. solids inventory very high), then blast wasting may be indicated	a. Increase wasting to reduce solids inventory b. Increase return sludge flow rate
7	a. Monitor Fed Sludge RR frequently to track incoming toxic load b. Divert toxic load away from aeration system, preferably to a place where it can be stored and then bled into the aeration system slowly c. If necessary, by-pass the plant to protect the aeration system and maintain treatment capability d. Periodically run Fed Sludge RR test using feed known to be acceptable (sucrose or dextrose) to monitor toxicity to sludge solids (identify sick sludge) e. Perform microscope examination of the sludge. Presence of inactive or encysted protozoans indicates potential toxicity	a. Try to maintain and protect plant by diverting toxic load and bleeding it into the system as slowly as possible b. If possible, switch to sludge reaeration mode to protect as much of the solids inventory as possible. If necessary, sacrifice part of plant and treatment efficiency to protect the sludge solids and to facilitate recovery after the toxic influent episode is over c. If the toxic material has accumulated in the sludge and made sludge inactive, discharge as much sludge as possible to solids disposal (except aerobic or anaerobic digesters) and, when toxic episode is over, go through plant start-up procedures

F/M Decreasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
	f. Convert to sludge reaeration mode of operation to protect sludge solids g. Identify source of toxic discharge and prevent recurrence of the discharge h. Notify the state regulatory agency of potential toxic discharge from plant and possibility of by-passing toxic load to protect the plant i. Try coagulation, chemical precipitation or activated carbon treatment in primary settling tanks to remove toxic materials. Toxic primary solids may upset solids conditioning and disposal systems. Dispose of them properly. j. Use coagulants in aeration basin or final clarifiers to trap solids and improve settling	d. Raise hell with the discharger of the toxic load, let him/her know the problems caused and make sure that he/she doesn't do it again e. Spend endless hours justifying the actions taken to state and federal regulatory agencies
8	a. Perform nutrient analysis on influent waste and feed nutrients as necessary b. Continue to monitor for nutrients and quit feeding nutrients when no longer needed c. Consider use of coagulants and coagulant aids to improve settling and solids capture during period of upset	a. Determine sources of nutrient deficient wastes and modify operations as necessary if this will be a long term continuing problem b. Consider using Kraus modification of activated sludge process if nutrient deficient wastes will be a continuing problem
9	Perform stabilization time tests and modify operations as necessary to provide adequate stabilization time in the aeration system	a. If settling rate and MLSS RR do not change, continue current operating practices b. If settling rate decreases and MLSS RR increases, then:

F/M Decreasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
		1) Decrease return rate to increase aeration detention time 2) Decrease wasting to increase solids inventory 3) If 1 and 2 don't work, move to sludge reaeration operating mode

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

PARAMETER MONITORED: MCRT *OBSERVED CONDITION:* MCRT Increasing

POSSIBLE CAUSE OF OBSERVED CONDITION:

Possible Condition	Observations and Data to Confirm Cause
1. Inadequate solids wasting causing solids inventory to increase	1. Settling Rate - increasing, no change or decreasing MLSS RR - decreasing, no change or increasing F/M - decreasing, constant or increasing Fed Sludge RR - about the same or increasing Influent Flow Rate - about the same Aeration Basin D.O. - about the same or decreasing

PROCESS CONTROL RESPONSE TO OBSERVED CONDITION:

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
1		a. If F/M is decreasing, settling rate is increasing and MLSS RR is decreasing then: 1) Increase wasting rate and reduce solids inventory to bring F/M and MCRT into normal ranges and affect long term reversal of trends in settling rate and MLSS RR 2) Increase return sludge rate to decrease aeration detention time and affect immediate reversal of trends in settling rate and MLSS RR observations

MCRT Increasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
		3) When F/M and MCRT are in optimum operating ranges, adjust return and waste rates as necessary to maintain optimum settling rate, MLSS RR, F/M and MCRT
		b. If F/M is increasing, settling rate decreasing and MLSS RR is increasing, then:
		1) Decrease wasting to increase solids inventory and MCRT more rapidly to respond to increasing load
		2) Decrease return to increase aeration detention time to handle increased load
		3) When F/M and MCRT are in optimum operating ranges, adjust return and waste rates as necessary to maintain optimum settling rate, MLSS RR, F/M and MCRT for new loading conditions (i.e, revert to normal process control procedures).
		c. If F/M, settling rate and MLSS RR remain constant as MCRT increases, then continue present operating practices because both load and solid inventory are increasing but are balanced. However, increase frequency of settling and MLSS RR testing because system may move out of balance as conditions continue to change

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

PARAMETER MONITORED: MCRT

OBSERVED CONDITION: MCRT Decreasing

POSSIBLE CAUSES OF OBSERVED CONDITION:

Possible Causes	Observation and Data to Confirm Cause
1. Excessive deliberate wasting causing solids inventory to decrease	1. Settling Rate - decreasing MLSS RR - increasing F/M - increasing Fed Sludge RR - about the same Influent Flow Rate - about the same Aeration Basin D.O. - about the same or increasing
2. High final effluent suspended solids causing the solids inventory to decrease	2. Settling Rate - decreasing MLSS RR - increasing F/M - increasing Fed Sludge RR - about the same Influent Flow Rate - about the same Aeration Basin D.O. - about the same or increasing

PROCESS CONTROL RESPONSES TO OBSERVED CONDITIONS:

Possible Causes	Immediate or Temporary Response	Long Term Corrective Action
1	a. Check final clarifier sludge blanket depth 1) If blanket is rising rapidly and solids washout is likely, then temporarily increase return rate to lower sludge blanket. Reduce return rate as soon as danger of solids washout is passed and implement long range corrective action. CAUTION: This may cause slow settling sludge problem to get worse before long range corrective actions take effect.	a. Decrease deliberate wasting to increase solids inventory b. Decrease return sludge rate to increase aeration detention time c. If a and b do not correct the problem, then go to sludge reaeration mode of operation d. When MCRT and F/M are back in normal ranges, resume normal operation control procedures

MCRT Decreasing (Continued)

Possible Causes	Immediate or Temporary Response	Long Term Corrective Action
	2) If the sludge blanket is not out of control, implement long term corrective actions	
2	Determine cause of high effluent suspended solids	
	a. High Sludge Blanket	
	1) Slow settling sludge (bulking) causes high sludge blanket with solids wash-out. Run settling test on MLSS samples diluted with final effluent	
	a. If diluted MLSS samples settle faster and concentrate well, then consider "blast" wasting to dilute sludge and lower the sludge blanket. Then implement long term corrective actions.	a.1) If sludge still slow settling after blast wasting, then: a. Decrease return to increase aeration detention time. Monitor blanket and response to high blanket conditions as necessary
	b. If diluted MLSS samples do not settle faster and concentration characteristics do not improve with dilution, increase return rate temporarily to lower blanket as in possible cause 1a response. Then implement long term corrective action	b. Decrease deliberate wasting to increase solids inventory c. Increase sludge aeration time by moving to sludge reaeration mode of operation 2) Same as possible cause 1 response
	2) If sludge blanket is high but not caused by slow settling solids, then check final clarifier for proper operation and design	
	a. Sludge collection, return or wasting systems not operating properly	
	1. Rake or collector drive mechanism broken or shut-off because or torque overload	a.1) Repair or reset

MCRT Decreasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
	2. Broken chains	a.2) Repair or replace
	3. Missing flights or scrapers	a.3) Repair
	4. Plugged collectors or pumps	a.4) Repair
	5. Pumps not operating	a.5) Repair or replace
	b. Hydraulic overload	b.1) Put additional clarifiers into service
		b.2) Reduce hydraulic load to clarifier, if possible
	c. Solids overlaod	c.1) Put additional clarifiers into service
		c.2) Reduce solids load to clarifier
		c.3) Take actions to produce a faster settling sludge a) Sludge reaeration b) Increase solids inventory c) Increase aeration detention time
		After above actions complete, reduce deliberate wasting to increase solids inventory to optimum range
	b. Sludge blankets are low but effluent solids are high	
	1) Clumping or floating sludge	1) Increase return to reduce solids detention time in final clarifier and adjust deliberate waste as appropriate to maintain solids inventory
	2) Improperly maintained clarifier weirs	2) Check and level clarifier weirs if needed. Reduce wasting to build solids inventory

MCRT Decreasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
	3) Unequal load distribution to multiple clarifiers	3a) Check weirs to verify that all clarifiers have same weir elevation. Adjust as needed
		b) Check inlet and effluent structures for obstructions. Remove obstructions
		c) Check and adjust flow distribution system
		d) Decrease deliberate wasting to increase solids inventory to optimum range
	4) Improperly designed final clarifier	4a) Check adequacy of weirs. Add or relocate weirs as indicated
		b) Block excess weir lengths if these cause local currents and solids carry-over
		c) Check adequacy of systems to dampen inlet flow velocities. Correct as needed
		d) Decrease deliberate wasting to increase solids inventory to optimum range

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

PARAMETER MONITORED: MLSS RR *CONDITION OBSERVED:* MLSS RR Increasing

POSSIBLE CAUSE OF OBSERVED CONDITION:

Possible Cause	Observations and Data to Confirm Cause
1. Increase in applied organic load	1. Settling Rate - decreasing F/M - increasing MCRT - no change or increasing slowly Fed Sludge RR - increasing or about the same Influent Flow Rate - about the same or increasing Aeration Basin D.O. - decreasing
2. Decrease in aeration basin detention time	2. Settling Rate - decreasing F/M - about the same MCRT - about the same Fed Sludge RR - about the same Influent Flow Rate - increasing or about the same Aeration Basin D.O. - increasing or about the same
3. Change in nature of organic load to a more slowly stabilized waste	3. Settling Rate - decreasing F/M - about the same MCRT - about the same Fed Sludge RR - about the same or decreasing Influent Flow Rate - about the same Aeration Basin D.O. - increasing or about the same
4. Decrease in solids inventory	4. Settling Rate - decreasing F/M - increasing MCRT - decreasing Fed Sludge RR - about the same Influent Flow Rate - about the same Aeration Basin D.O. - increasing or about the same

MLSS RR Increasing (Continued)

Possible Cause	Observations and Data to Confirm Cause
5. Decrease in solids aeration time	5. Settling Rate - decreasing F/M - about the same MCRT - about the same Fed Sludge RR - about the same Influent Flow Rate - about the same Aeration Basin D.O. - increasing or about the same
6. Increase in mixed liquor temperature	6. Settling Rate - increasing F/M - about the same MCRT - about the same Fed Sludge RR - increasing or about the same Influent Flow Rate - about the same Aeration Basin D.O. - decreasing

PROCESS CONTROL RESPONSE TO OBSERVED CONDITION:

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
1	a. Determine conditions associated with increase in applied organic load as described for the F/M Increasing case and modify responses accordingly b. Check sludge blanket depth in final clarifier and respond to high blanket conditions as appropriate	a. Decrease return rate to increase aeration basin detention time b. Decrease wasting to increase solids inventory c. Increase aeration detention time and sludge aeration time if a and b don't work 1. Place additional aeration basins in service 2. Switch to sludge reaeration mode of operation
2	a. Determine cause of decreased aeration detention time	
	1. Increase in influent flow rate	a1a) Decrease return sludge flow rate to increase aeration detention time

MLSS RR Increasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
		b) Decrease waste rate to increase solids inventory c) Increase aeration detention time 1) Place additional aeration basins into service 2) Switch to sludge reaeration mode of operation
	2. Excessive return activated sludge flow rate	a2a) Decrease return sludge flow rate b) Decrease waste rate, if decrease in return rate doesn't correct the problem
	b. Monitor sludge blanket in final clarifier and respond to high blanket as appropriate	
3	a. Perform stabilization time RR test, identify new source and determine new conditions for optimum system performance if the change in waste characteristics will be long term	a. Increase aeration detention time 1) Decrease return rate 2) Add aeration basins 3) Use sludge reaeration mode of operation b. Increase solids inventory by decreasing waste sludge flow rate c. Determine new optimum ranges for F/M and MCRT to correspond to new loading conditions and adjust normal operating procedures as necessary
4	a. Identify cause of decrease in solids inventory as described for the MCRT Decreasing, pages H11.7.16 -H11.7.19, and F/M Increasing, pages H11.7.1 - H11.7.7, cases and take appropriate corrective actions	a. Decrease wasting to increase solids inventory b. Decrease return sludge rate to increase aeration detention time

MLSS RR Increasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
		c. Use sludge reaeration mode of operation
5	a. Check aeration detention time and if aeration detention time has decreased, take responses given for possible cause 2	a. If aeration detention time has decreased, take possible cause 2 responses
	b. Check for solids accumulation in final clarifier. Determine cause for solids accumulation in final clarifier and take corrective responses. Most likely causes:	
	1) Improperly operating sludge collection, sludge return or sludge wasting systems	b1) Correct problems in clarifier
	2) Solids overload in clarifiers	b2) Use additional clarifiers or take action to develop faster settling sludge
	c. This may be a planned effect as a result of decision to change operating mode from sludge reaeration by moving toward conventional mode of operation	c. Monitor system closely to prevent over response in process conditions caused by mode change
6	a. Check influent wastewater temperature. If wastewater and mixed liquor temperatures have have increased, take long term corrective action	a. Determine new optimum ranges for F/M and MCRT to correspond to increased temperature in system 1) Decrease solids inventory 2) Decrease aeration detention time
	b. If process wastewater temperatures have not increased, check laboratory procedures used in RR test	b. Correct laboratory procedures
	c. If process temperature has not increased and laboratory procedures are O.K., then check for other cause for increased MLSS RR	

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

PARAMETER MONITORED: MLSS RR *CONDITION OBSERVED:* MLSS RR Decreasing

POSSIBLE CAUSE OF OBSERVED CONDITION:

Possible Cause	Observations and Data to Confirm Cause
1. Decrease in applied organic load	1. Settling Rate - increasing F/M - decreasing MCRT - no change or decreasing slowly Fed Sludge RR - decreasing or about the same Influent Flow Rate - about the same or decreasing Aeration Basin D.O. - increasing
2. Increase in aeration basin detention time	2. Settling Rate - increasing F/M - about the same MCRT - about the same Fed Sludge RR - about the same Influent Flow Rate - decreasing or about the same Aeration Basin D.O. - decreasing or about the same
3. Change in nature of organic load to a more rapidly stabilized waste	3. Settling Rate - increasing F/M - about the same MCRT - about the same Fed Sludge RR - about the same or decreasing Influent Flow Rate - about the same Aeration Basin D.O. - decreasing or about the same
4. Increase in solids inventory	4. Settling Rate - increasing F/M - decreasing MCRT - increasing Fed Sludge RR - about the same Influent Flow Rate - about the same Aeration Basin D.O. - decreasing or about the same

MLSS RR Decreasing

Possible Cause	Observations and Data to Confirm Cause
5. Increase in solids aeration time	5. Settling Rate - increasing F/M - about the same MCRT - about the same Fed Sludge RR - about the same Influent Flow Rate - about the same Aeration Basin D.O. - decreasing or about the same
6. Decrease in mixed liquor temperature	6. Settling Rate - decreasing F/M - about the same MCRT - about the same Fed Sludge RR - about the same or decreasing Influent Flow Rate - about the same Aeration Basin D.O. - increasing
7. Presence of toxic or inhibitory substances	7. Settling Rate - decreasing, possible deflocculation F/M - decrease or no change depending on measurement technique MCRT- about the same Fed Sludge RR - decreasing - very low - load factor < 1 Influent Flow Rate - about the same Aeration Basin D.O. - increasing
8. Nutrient deficient wastewater	8. Settling Rate - decreasing, possible deflocculation, possible dispersed growth F/M - decrease or no change depending on measurement technique MCRT - about the same Fed Sludge RR - decreasing, low Influent Flow Rate - about the same Aeration Basin D.O. - increasing

MLSS RR Decreasing (Continued)

PROCESS CONTROL RESPONSE TO OBSERVED CONDITION:

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
1	a. Determine conditions associated with decrease in applied organic load as described for F/M Decreasing, pages H11.7.8 - H11.7.9. Modify response accordingly.	a. Increase return sludge flow rate to decrease aeration detention time b. Increase wasting rate to decrease solids inventory
	b. Check final clarifier solids in the final clarifier	c. Move toward conventional operating mode if operating with sludge reaeration to decrease sludge aeration time
2	Determine cause of increase in aeration detention time	
	a. Decrease in influent flow rate	a1) Respond as indicated for possible cause 1 2) Take aeration tanks out of service
	b. Return sludge flow rate too low	b. Increase return sludge flow rate. If increase in return rate doesn't solve problem, then increase wasting to reduce solids inventory and solids aeration time
	c. Too much aeration volume in use	c. Decrease aeration volume in use
3	Perform stabilization time test, identify source of change in organic load, and if change in load is permanent, determine new optimum ranges for parameters to treat new load	a. Decrease aeration detention time by: 1) Increasing return sludge flow rate 2) Removing aeration basin from service b. Decrease sludge aeration time by: 1) Increasing wasting to reduce solids inventory 2) Moving from sludge reaeration to conventional operating modes

MLSS RR Decreasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
4	a. Check wasting rate to determine adequacy of wasting program	a. Increase wasting to reduce solids inventory
		b. Increase return sludge flow rate to decrease aeration detention time
		c. Move from sludge reaeration mode of operation to conventional mode of operation
5	a. Check aeration detention time. If aeration detention has increased, take responses listed for possible cause 2	a. Make responses for possible cause 2 if aeration basin time has increased
	b. Check final clarifier to determine whether final clarifier solids have been moved from final clarifier to the aeration basin. Identify cause for depletion of clarifier solids inventory and take appropriate response. Most likely cause is fast settling solids coupled with too high a return rate	b. Take appropriate action to produce solids which settle more slowly 1) Decrease aeration detention time by increasing return sludge rate 2) Decrease solids inventory by increasing wasting rate 3) Move from sludge reaeration to conventional mode of operation
	c. This may be a planned response caused by moving from conventional mode of operation to sludge reaeration mode of operation	c. Continue planned transition from conventional to sludge reaeration mode adjusting return and waste as appropriate to maintain balanced system
6	a. Check mixed liquor and influent waste for decrease in temperature. If mixed liquor temperature has decreased then increase solids inventory and determine new optimum ranges for F/M and MCRT to correspond to lower temperature	a1) Decrease wasting to increase solids inventory a2) Decrease return sludge flow rate to increase aeration detention time

MLSS RR Decreasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
	b. If process temperatures have not changed, check laboratory procedures for MLSS RR test	b. Correct laboratory procedures
7	a. Check Fed Sludge RR. If load factor is less than 1 suspect toxic or inhibitory load	a. Take corrective actions described as possible cause 7 for F/M Decreasing case, pages H11.7.11 - H11.7.12
	b. Perform microscopic examination of sludge. Presence of inactive or encysted protozoans is indicative of toxic load	
	c. Take toxic or inhibitory load responses described as possible cause 7 for F/M Decreasing, page H11.7.9.	
8	a. Analyze for nutrients	a. Take corrective actions described as possible cause 8 for F/M Decreasing, page H11.7.12
	b. Take responses given as possible cause 8 for F/M Decreasing, page H11.7.9.	

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

PARAMETER MONITORED: Settling Rate

CONDITION OBSERVED: Settling Rate Increasing

POSSIBLE CAUSE OF OBSERVED CONDITION:

Possible Cause	Observations and Data to Confirm Cause
1. Decrease in applied organic load	1. MLSS RR - decreasing F/M - decreasing MCRT - about the same Fed Sludge RR - decreasing or about the same Influent Flow Rate - about the same or decreasing Aeration Basin D.O. - increasing Observations in Settling Test - possible pin floc, ashing or rising sludge
2. Increase in aeration detention time	2. MLSS RR - decreasing F/M - about the same MCRT - about the same Fed Sludge RR - about the same Influent Flow Rate - decreasing or about the same Aeration Basin D.O. - increasing or about the same Observations in Settling Test - possible pin floc, ashing or rising sludge
3. Increase in solids aeration time	3. MLSS RR - decreasing F/M - about the same or decreasing MCRT - about the same or increasing Fed Sludge RR - about the same Influent Flow Rate - about the same or decreasing Aeration Basin D.O. - about the same or decreasing Observations in Settling Test - possible pin floc, ashing or rising sludge

Settling Rate Increasing (Continued)

Possible Cause	Observations and Data to Confirm Cause
4. Increase in solids inventory	4. MLSS RR - decreasing F/M - decreasing MCRT - increasing Fed Sludge RR - about the same Influent Flow Rate - about the same Aeration Basin D.O. - about the same or decreasing Observations in Settling Test - possible pin floc, ashing or rising sludge
5. Increase in mixed liquor temperature	5. MLSS RR - increasing F/M - about the same MCRT - about the same Fed Sludge RR - about the same or increasing Influent Flow Rate - about the same Aeration Basin D.O. - decreasing Observations in Settling Test - possible pin floc or rising sludge
6. Change in nature of organic load to more rapidly stabilized waste	6. MLSS RR - decreasing F/M - about the same or increasing MCRT - about the same Fed Sludge RR - about the same or increasing Influent Flow Rate - about the same Aeration Basin D.O. - about the same or decreasing

PROCESS CONTROL RESPONSE TO OBSERVED CONDITION:

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
1	a. Determine conditions associated with decrease in applied organic load as described for F/M Decreasing and modify response accordingly (pages H11.7.8 - H11.7.9)	a1) Increase return sludge flow rate to decrease aeration detention time 2) Increase wasting to reduce solids inventory and bring F/M into normal operating range. Determine optimum solids inventory (F/M and MCRT) ranges to correspond to new loading conditions

Settling Rate Increasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
		3) If operating in sludge reaeration mode, move toward conventional mode of operation to decrease oxidative pressures
	b. Observe settling test supernate and sludge blanket closely. 1) Appearance of pin floc indicates that system may be nitrifying. Monitor aeration basin pH and D.O. closely. Verify by running NH_3-N NO_3^--N and NO_2^--N test on aeration basin effluent and influent	b1) If nitrification is desirable operation, take system to full nitrification by decreasing wasting to build solids inventory and operate in low F/M and long MCRT ranges to encourage nitrification. Determine optimum system parameter ranges for nitrification. If pH falls, use lime or soda ash to control pH in aeration basin near pH = 7.0. Increase air supply to maintain at least 2 mg/l D.O. throughout aeration basin. Increase return sludge flow rate to prevent solids accumulation and denitrification in the final clarifier 2) If nitrification is undesirable operating condition, then take actions listed in response a
	2) Allow settled sludge to remian in settleometer for 2-4 hours and observe sludge blanket in settleometer periodically. If sludge rised in less than two hours, system is probably nitrifying with possible denitrification in the final clarifier	Take corrective action responses listed above as appropriate
	3) Appearance of ash indicates that system is operating with very old sludge which is into endogenous respiration	Reduce solids inventory and sludge aeration time to avoid turbid, possibly excess suspended solids, final effluent

Settling Rate Increasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
2	a. Determine conditions associated with increase in aeration detention time. Most likely conditions include:	
	1) Decrease in influent flow rate	a1) Increase return sludge flow rate to decrease aeration detention time 2) Increase wasting to lower solids inventory 3) Move from sludge reaeration toward conventional mode of operation
	2) Return sludge flow rate is too low. Check final clarifier for solids accumulation. Check return system for plugged pumps or sludge collectors	a2) Increase return sludge flow rate
	3) Too much aeration basin volume being used	a3) Decrease aeration volume in use
3	Determine cause of increase in solids aeration time as described as possible cause 5 for MLSS RR Decreasing, page H11.7.25	Take appropriate corrective action as given in possible cause 5 for MLSS RR Decreasing, page H11.7.27
4	a. Check wasting rate to determine adequacy of wasting program	a) Increase wasting to reduce solids inventory b) Increase return sludge flow rate to decrease aeration detention time c) Move from sludge reaeration toward conventional mode of operation
5	a. Check settling test for indications of possible nitrification/denitrification	a) Respond as for possible cause 3

Settling Rate Increasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
	b. Verify mixed liquor temperature increase as described as possible cause 6 for MLSS RR Increasing, page H11.7.21	b. Take corrective action responses listed as possible cause 6, MLSS RR Increasing, page H11.7.23
6	Take responses given as possible cause 3, MLSS RR Decreasing, page H11.7-24	Take corrective action responses given as possible cause 3, MLSS RR Decreasing, page H11.7.26

Activated Sludge Process Troubleshooting

Problem Identification and Process Control Response

PARAMETER MONITORED: Settling Rate

CONDITION OBSERVED: Settling Rate Decreasing

POSSIBLE CAUSE OF OBSERVED CONDITION:

Possible Cause	Observations and Data to Confirm Cause
1. Applied organic load increasing	1. MLSS RR - increasing F/M - increasing MCRT - about the same or slowly increasing Fed Sludge RR - increasing or about the same Influent Flow Rate - about the same or increasing Aeration Basin D.O. - decreasing Observations in Settling Test - possible straggler floc
2. Aeration detention time decreasing	2. MLSS RR - increasing F/M - about the same MCRT - about the same Fed Sludge RR - about the same Influent Flow Rate - increasing or about the same Aeration Basin D.O. - about the same or increasing Observations in Settling Test - Possible straggler floc
3. Change in nature of organic load to more slowly stabilized waste	3. MLSS RR - increasing F/M - about the same or increasing MCRT - about the same Fed Sludge RR - about the same or increasing Influent Flow Rate - about the same Aeration Basin D.O. - increasing
4. Decrease in solids inventory	4. MLSS RR - increasing F/M - increasing MCRT - decreasing Fed Sludge RR - about the same Influent Flow Rate - about the same Aeration Basin D.O. - increasing or about the same Observations in Settling Test - Possible straggler floc

Settling Rate Decreasing (Continued)

Possible Cause	Observations and Data to Confirm Cause
5. Decrease in solids aeration time	5. MLSS RR - increasing F/M - about the same MCRT - about the same Fed Sludge RR - about the same Influent Flow Rate - about the same or decreasing Aeration Basin D.O. - about the same
6. Decrease in mixed liquor temperature	6. MLSS RR - decreasing F/M - about the same MCRT - about the same Fed Sludge RR - about the same or decreasing Influent Flow Rate - about the same Aeration Basin D.O. - increasing
7. Toxic or inhibitory substances present	7. MLSS RR - decreasing F/M - about the same MCRT - about the same Fed Sludge RR - decreasing Influent Flow Rate - about the same Aeration Basin D.O. - increasing Observations in Settling Tank - deflocculation or dispersed growth appearance Microscopic Observations - Inactive or encysted protozoans
8. Nutrient deficient wastewater	8. MLSS RR - decreasing F/M - decreasing or no change depending on test procedures MCRT - about the same Fed Sludge Rate - decreasing - low Influent Flow Rate - about the same Aeration Basin D.O. - increasing Observations in Settling Test - possible deflocculation, possible dispersed growth

Settling Rate Decreasing (Continued)

PROCESS CONTROL RESPONSE TO OBSERVED CONDITION:

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
1	a. Determine conditions associated with increase in organic load as described for F/M Increasing cases, page H11.7.1 - H11.7.2. Modify corrective actions as appropriate.	a1) Decrease return sludge flow rate to increase aeration detention time 2) Decrease wasting to increase solids inventory and define optimum ranges in F/M and MCRT to correspond to new loading conditions 3) Move from conventional operating mode to sludge reaeration mode to increase oxidative pressures
	b. Observation of straggler floc in the settling test indicates that sludge is young and bulking is a possibility if corrective actions are not taken	b. Take corrective actions listed above
2	a. Determine conditions causing the decrease in aeration detention time as described as possible cause 2 for MLSS RR Increasing, page H11.7.20	Take corrective action responses given as possible cause 2 for MLSS RR Increasing, page H11.7.21 - H11.7.22
3	Take response given as possible cause 3, MLSS RR Increasing, page H11.7.20	Take corrective actions given as possible cause 3, MLSS RR Increasing page H11.7.22
4	Identify cause for decrease in solids inventory as described for MCRT Decreasing, page H11.7.16, and F/M Increasing, page H11.7.1 - H11.7.2, cases. Take appropriate corrective actions.	a. Decrease wasting to increase solids inventory b. Decrease return sludge rate to increase aeration detention times c. Use sludge reaeration mode of operation
5	Take responses as described in possible cause 5 for MLSS RR Increasing, page H11.7.21	Take corrective actions as described in possible cause 5, MLSS RR Increasing, page H11.7.23

Settling Rate Decreasing (Continued)

Possible Cause	Immediate or Temporary Response	Long Term Corrective Action
6	Take responses as described in possible cause 6, MLSS RR Decreasing, page H11.7.25	Take corrective actions as described in possible cause 6, MLSS RR Decreasing, pages H11.7.27 - H11.7.28
7	Take responses as described in possible cause 7, MLSS RR Decreasing, page H11.7.25	Take corrective actions as described in possible cause 7, F/M Decreasing, page H11.7.28
8	Take responses as described in possible cause 8, MLSS RR Decreasing, page H11.7.25	Take corrective actions as described in possible cause 8, F/M Decreasing, page H11.7.28

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 8: Visual Observations in Troubleshooting

Lesson 8 of 14 lessons Recommended Time: 60 minutes

Purpose: Visual inspection of the activated sludge process offers a quick and simple procedure to gain preliminary information on possible problems in the activated sludge process. It is essential that the troubleshooter know what to look for and how to interpret the results during the visual inspection of the activated sludge treatment system. This lesson presents information about and illustrates the items which should be observed during the visual inspection of the activated sludge process.

Trainee Entry Level Behavior: The trainees should have achieved the learning objectives specified for Lessons 1 - 7, Unit 11, before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. From memory, describe how the process of troubleshooting is applied to activated sludge systems by listing data and observations needed to evaluate the process and identify the problems.

2. From memory, describe the importance of proper operation of preliminary and primary treatment units to the overall performance efficiency of the activated sludge process.

3. From memory, list the data and observations to be made during the inspection of pumps and meters and explain how these observations may be indicators of operational problems in the activated sludge system.

4. From memory, list the visual observations to be made at the aeration basin and explain their significance in identifying activated sludge operating problems.

5. From memory, list the visual observations to be made at the final clarifier and explain their significance in evaluating activated sludge system performance.

6. Shown photographs of aeration basin and final clarifier conditions, identify the possible problem at the facility and obtain additional data needed to confirm the problem and demonstrate ability to interpret visual observations by solving problems posed by the instructor.

Instructional Approach: Illustrated lecture with trainee discussion and problem solving.

Lesson Schedule: The sixty minutes allocated for this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 10 minutes	Introduce Lesson
10 - 20 minutes	Preliminary and Primary Treatment Observations
20 - 25 minutes	Flow Rates and Meters
25 - 35 minutes	Aeration Tank Observations
35 - 45 minutes	Final Clarifier Observations
45 - 60 minutes	Trainee Problem Solving

Trainee Materials Used in Lesson:

1. West, A. W., *Operational Control Procedures for the Activated Sludge Process, Part I*, U. S. Environmental Protection Agency, National Training and Operational Technology Center, Cincinnati, Ohio.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 11.8.1 - 11.8.25, Unit 11, Lesson 8.

2. Slides 179.2/11.8.1 - 179.2/11.8.67.

Instructor Materials Recommended for Development: None

Additional References: None

Classroom Set-Up: As specified for Unit 11, Lesson 1.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Introduction (10 minutes)	Use Slide 179.2/11.8.1 Slide 179.2/11.8.1 is a blank
A. Note that this lesson will look at applying the *Process of Troubleshooting* to activated sludge systems with emphasis on what can be learned by visually inspecting the plant.	
B. The Process of Troubleshooting 1. Use Slide 179.2/11.8.2 to briefly review the major steps in the *Process of Troubleshooting* (Refer to Unit 2, Lesson 2). 2. Note that the exercise in Unit 11, Lesson 7 focused on steps 1 and 2 by identifying possible problems and appropriate control responses to observed changes in process control testing data. 3. This lesson focuses on use of visual observations as guides or clues to possible problems.	Use Slide 179.2/11.8.2 Slide 179.2/11.8.2 is a word slide which reads: "Solving a Problem with *The Process of Troubleshooting* Step 1: Analyze and Learn Step 2: Formulate Alternative Solutions Step 3: Take Corrective Actions Step 4: Observe and Test Step 5: Long Range Implementation"
C. Cause of Poor Activated Sludge Performance 1. Use Slide 179.2/11.8.3 to briefly review the major causes of problems in activated sludge which were identified in Unit 11, Lesson 7. a. Controllable Factors 1) Internal plant hydraulics 2) Sludge quality and quantity b. Uncontrollable Factors 1) Applied load 2) Toxics	Use Slide 179.2/11.8.3 Slide 179.2/11.8.3 is a word slide which reads: "Causes of Poor Activated Sludge Performance · Controllable Factors · Hydraulic · Sludge · Uncontrollable Factors · Organic Load · Toxics"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
c. Lesson 7 actually identified many variations on these broad categories.	
2. Use Slide 179.2/11.8.4 to briefly review the types of hydraulic problems which may affect activated sludge systems.	Use Slide 179.2/11.8.4 Slide 179.2/11.8.4 is a word slide which reads: "Activated Sludge - Hydraulic Problems · Overload · Internal Imbalance · Short Circuiting · Flow Variability · Surging"
3. Use Slide 179.2/11.8.5 to briefly review principal problems affecting sludge quality.	Use Slide 179.2/11.8.5 Slide 179.2/11.8.5 is a word slide which reads:
a. Sludge 1) Too old 2) Too young	"Common Sludge Problems · Sludge Age · Too Old · Too Young
b. Sludge Quantity 1) Too much 2) Too little	· Sludge Quantity · Too Much · Too Little"
c. Lesson 7 identified many possible causes of these sludge conditions.	
D. Problem Identification 1. Use Slide 179.2/11.8.6 to briefly review methods to identify sludge quality problems.	Use Slide 179.2/11.8.6 Slide 179.2/11.8.6 is a word slide which reads: "Means of Identifying Sludge Related Problems
2. Note that lesson 7 stressed the interpretation of laboratory data in problem identification	

LESSON OUTLINE

3. This lesson will focus on the visual indicators of possible problems.

II. Preliminary and Primary Treatment Observations (10 minutes)

A. Knowledge of waste characteristics and proper operation of preliminary and primary treatment systems is essential to achieving good activated sludge system performance.

B. Preliminary and primary treatment was covered in detail in Unit of Instruction 4. This section is just a reminder of the imporatnce of these units to overall system performance.

C. Monitor influent waste characteristics

1. Must know what and how much is coming into the plant

2. Slide 179.2/11.8.7 shows an operator monitoring influent pH to remind us of the importance of regular monitoring of influent characteristics.

D. Identify internal recycles

1. Ask class to identify this problem and offer possible causes

2. Solutions sought

a. Probably a septic waste

b. Possible causes

1) Septic sewage

KEY POINTS & INSTRUCTOR GUIDE

- Visual Observations
  Color
  Foam

- Analysis of Control Parameters
  F/M, MCRT, RR, MLSS

- Settling Results"

Use Slide 179.2/11.8.7
Slide 179.2/11.8.7 is a photograph showing an operator monitoring the influent pH.

Use Slide 179.2/11.8.8
Slide 179.2/11.8.8 is a photograph of the plant headworks filled with a black septic liquid.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2) Dump of septage by a septage handler 3) Internal recycles such as digester or thickener supernate	
3. Slide 179.2/11.8.9 shows a similar problem. a. Ask class "What other observation should be made here?" b. Answer: Is flow equally distributed to multiple primary clarifiers?	Use Slide 179.2/11.8.9 Slide 179.2/11.8.9 is a photograph showing an inlet flow distribution box filled with dark colored liquid (digester supernate).
4. Use the two slide example to stress the importance of inspecting the system and the ease with which some potential problems can be identified by simple observation.	
E. Primary Clarifier Observation 1. Use next two slides to show a poorly operated primary clarifier. 2. Ask class to identify potential downstream problems which may be caused by poor primary clarifier operation and possible causes for poor primary clarifier performance. a. Downstream problem: excessive load to aeration because settleable solids are not being removed in the primary clarifier. b. Cause of poor primary clarifier performance 1) High sludge blanket 2) Turbulence in clarifier	Use Slide 179.2/11.8.10 and 179.2/11.8.11 Slides 179.2/11.8.10 and 179.2/11.8.11 are photographs showing a primary clarifier with large quantity of solids carryover.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3) Slow settling or non-settleable solids in influent 4) Others?	
3. In this case the problem was caused by an industrial discharger not properly pretreating the waste. The discharger (a brewery) claimed to be operating both load equalization and primary settling systems. Obviously something is wrong as evidenced by the operators having to manually remove spent grains from the primary clarifier at the municipal treatment plant.	Use Slide 179.2/11.8.12 Slide 179.2/11.8.12 is a photograph showing operators cleaning the primary clarifier shown in the previous slides. Note that the "primary sludge" had to be manually lifted from the clarifier. The "sludge" is spent grains from a brewery.
III. Flow Rates and Meters (5 minutes) A. Use Slide 179.2/11.8.13 to indicate locations where observations should be made in the inspection of an activated sludge plant. First, we will discuss pumps, meters and flow rates.	Use Slide 179.2/11.8.13 Slide 179.2/11.8.13 is a word slide which reads: "Observations · Meters · Aeration Tanks · Clarifiers"
B. Flows to measure 1. Briefly review the flows to be metered 2. Discuss the significance of each to process performance and troubleshooting	Use Slide 179.2/11.8.14 Slide 179.2/11.8.14 is a word slide which reads: "Record Discharge Rates Primary Effluent to Aeration Return Sludge from Clarifier Excess Sludge to Waste Air to Aeration"
C. Observations of Meters 1. Describe Slide 179.2/11.8.15 2. Ask class to identify possible causes for the observed activity. a. Pump surges	Use Slide 179.2/11.8.15 Slide 179.2/11.8.15 is a photograph which shows an operator using a stop watch and flow totalizer to estimate flow rates. The flow recorder chart shows a rapidly fluctuating flow being measured.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. Cycling pump c. Improper controllers on pump d. Turbulence at the flow sensor e. Others?	
3. Note that operator determined flow rates by averaging the totalizer readings.	
4. Contrast the above case with a good recorder display.	Use Slide 179.2/11.8.16 Slide 179.2/11,8.16 is a photograph showing strip chart flow recorders on display panel.
5. Ask class what is most likely cause of the rapid fluctuations in flow shown on this chart. a. On-off level control of constant speed pump b. Impact on system: Hydraulic surges which upset process	Use Slide 179.2/11.8.17 Slide 179.2/11.8.17 is a photograph showing high frequency swings between maximum and minimum flow rates on circular flow chart.
D. Flow Control 1. Use Slide 179.2/11.8.18 to indicate problems which may be caused by poor meter and controller placement. a. Meter and flow indicator in the pump well b. Manually operated valve on top c. Recorder in the control building in the background d. It took three men to change and adjust the flow	Use Slide 179.2/11.8.18 Slide 179.2/11.8.18 is a photograph showing two operators outside an open cover to a below grade pump.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Contrast the above to the remote control flow adjustments illustrated in the next two photographs.	Use Slide 179.2/11.8.19 Slide 179.2/11.8.19 is a photograph of an operator adjusting the display panel set point of a flow controller.
	Use Slide 179.2/11.8.20 Slide 179.2/11.8.20 is a photograph showing a power driven valve near the aeration basin.
3. Ask class "Which plant routinely monitored and adjusted flow rates?"	
4. Design tips	Use Slide 179.2/11.8.21 Slide 179.2/11.8.21 is a photograph of a remotely controlled vari-drive on a return sludge pump.
a. Provide remote controlled variable speed pumps for sludge return.	
b. A separate waste sludge pump with metering and controls is a good design feature in activated sludge plants.	Use Slide 179.2/11.8.22 Slide 179.2/11.8.22 is a photograph of a separate waste sludge pump.
IV. Aeration Tank Observations (10 minutes)	Use Slide 179.2/11.8.23 Slide 179.2/11.8.23 is a word slide which reads: "Aeration Tank Observations"
A. Monitor aeration basin D.O.	Use Slide 179.2/11.8.24 Slide 179.2/11.8.24 is a photograph showing an operator laying on the edge of the aeration tank holding a D.O. meter and probe in the black mixed liquor.
1. Ask class to critique Slide 179.2/11.8.24	
a. Safety hazards	
b. Short lead	
c. Surface measurement only	
d. Danger of losing meter if it slips	
e. Possible septic or low D.O. mixed liquor	

LESSON OUTLINE

2. Key off above points to illustrate good D.O. measurement in aeration basin.
    a. Long lead with extension pole for probe to measure D.O. in bottom of tank as well as the top.
    b. Above is safer.

B. Possible surface aerator problems

1. Plants without primary clarifiers
    a. Ask class "What problems might occur in plants without primary clarifiers such as this contact stabilization plant?"
        1) Rags
        2) Grit
    b. Use this slide to illustrate the the possible problems
        1) Rags decrease aerator efficiency
        2) Discuss safety hazards
            a) No life line
            b) No life jacket
            c) No protective clothing (gloves)
            d) Smoking
            e) Others?
2. Inadequate Mixing
    a. Ask class to identify possible problems here.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.8.25
Slide 179.2/11.8.25 is a photograph showing an operating surface aerator in a contact stabilization plant.

Use Slide 179.2/11.8.26
Slide 179.2/11.8.26 is a photograph showing an operator standing on a surface mechanical aerator removing rags from the turbine blades. The operator has no life line or life jacket; he is not wearing gloves and he's smoking.

Use Slide 179.2/11.8.27
Slide 179.2/11.8.27 is a photograph of an aeration basin with two surface mechanical aerators and shows

LESSON OUTLINE

1) Poor mixing

2) Possibly insufficient oxygen supply

b. Relate observations in slide to above problems.

3. Poor control of aeration rate

a. Use Slide 179.2/11.8.28 to illustrate the effect of reducing surface mechaincal aerator speed.

1) Power proportional to speed squared.

2) Reduce speed by 1/2 and reduce mixing and oxygen transfer energy transmitted to the liquid to 1/4.

b. Slide shows plant where problem was too much D.O. Tried to control D.O. by setting alternate aerators at full and half speed respectively. Note the effect. Both oxygen transfer and mixing limitations.

c. Most surface mechanical aerators only have two speed settings

1) Off

2) On

but some have three speed settings

1) Off

2) 1/2 maximum

3) Maximum

C. Diffused Air Systems

KEY POINTS & INSTRUCTOR GUIDE

large accumulations of foam in the corners of the aeration basin

Use Slide 179.2/11.8.28

Slide 179.2/11.8.28 is a photograph showing a bank of surface mechanical aerators. The forward most aerator is at the full-speed setting. The second aerator is at the half-speed setting.

LESSON OUTLINE

1. Preferable to surface mechanical aerators from a process control point of view.
2. Plugged or missing diffusers
    - a. Ask class to identify the problems here
    - b. Problems
        - 1) Short circuiting of air supply
        - 2) Inadequate mixing
        - 3) Probably low D.O.
    - c. Caused by a missing diffuser.
3. Discuss the importance of regularly scheduled preventive maintenance on diffuser systems.

D. Examples of Diffused Air Systems

1. Conventional Spiral Flow
    - a. Placement of diffusers along one wall creates spiral flow pattern down aeration tank.
    - b. Normally give good mixing and good aeration efficiency.
    - c. Some persons are concerned that spiral flow pattern can create a center core of flow which is poorly mixed.
    - d. Point out good feature in slide that diffusers can be lifted from the tank easily for inspection and replacement of socks.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.8.29

Slide 179.2/11.8.29 is a photograph showing the surface of an aeration tank with a diffused air system. Photo shows large quantity of air breaking the surface from one diffuser while adjacent diffusers have little or no air flow. Problem is short circuiting of air caused by a missing diffuser.

Use Slide 179.2/11.8.30

Slide 179.2/11.8.30 is a photograph showing normal diffuser placement along one wall of the aeration basin. The basin is empty.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Turbine with air spargers	Use Slide 179.2/11.8.31 Slide 179.2/11.8.31 is a photograph showing an empty aeration tank fitted with sparge-turbine type aerators.
a. Point out major parts of the aeration system	
1) Turbines for mixing and bubble shear	
2) Sparger ring	
b. Give good mixing and air transfer while needing a smaller air supply. Permits independent control of air and mixing.	Use Slide 179.2/11.8.32 Slide 179.2/11.8.32 is a photo showing the surface liquid pattern created by sparge-turbine aerator.
3. Cross-Flow Placement of Diffusers	Use Slide 179.2/11.8.33 Slide 179.2/11.8.33 is a photo of an empty aeration tank fitted with diffusers placed across the tank width.
a. Similar to spiral flow system except for diffuser placement.	
b. Eliminate potential coring problem.	
c. Provides good mixing and good oxygen transfer.	Use Slide 179.2/11.8.34 Slide 179.2/11.8.34 is a photo showing surface liquid pattern produced by cross-row placement of diffusers. An empty aeration tank is shown beside the filled tank.
d. Note color of foam and mixed liquor	
1) Small amount of crisp tan foam	
2) Deep tan color to mixed liquor	
3) Condition seen with good sludge quality	
4. Swirl Aerator	Use Slide 179.2/11.8.35 Slide 179.2/11.8.35 is a photograph showing a swirl aerator in an empty aeration basin.
a. Note aerator placement at 45° angle to direction of flow	
b. Good feature is relatively coarse bubble diffusers which are more resistant to plugging.	Use Slide 179.2/11.8.36 Slide 179.2/11.8.36 is a close-up photo of the swirl aerator bubblers.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
c. Gives good mixing and good oxygen transfer.	Use Slide 179.2/11.8.37 Slide 179.2/11.8.37 is a photo of the liquid surface pattern produced by a swirl aerator.
E. Significance of Surface Foam	
1. Color, quantity and texture of foam on the aerator is an excellent indicator of possible problems.	
2. Billowing white foam	Use Slide 179.2/11.8.38 Slide 179.2/11.8.38 is a photo of an aeration tank covered with billowing white foam.
a. Ask class "What does this slide tell you about the plant?"	
1) Possible high detergents causing foam.	
2) Possible young sludge	
b. Tell class that plants operating at high F/M, low MCRT and low solids inventory tend to produce billowing white foam. Usually associated with a high MLSS RR and slow settling (possibly a bulking sludge). May see straggler floc.	
c. When you see billowing white foam like that in the slide, it is a good sign that you need to decrease wasting to build the solids inventory.	
3. Thick gelatenous brown foam	Use Slide 179.2/11.8.39 Slide 179.2/11.8.39 is a photograph showing an aeration tank covered with a thick, gelatenous brown foam.
a. Ask class "What does this picture tell you about the plant?"	
b. Probably an old fast settling sludge which is nitrifying.	
c. Usually associated with a low F/M,	

LESSON OUTLINE

long MCRT, high solids inventory sludge. Sludge usually has a low MLSS RR and settles rapidly. Effluent is usually turbid. May have pin floc or ashing.

4. Beware - Your Eyes Can Deceive You

   a. Ask class "What does this picture tell you about the plant?"

   b. Class will probably respond: young sludge.

   c. Not true. This foam is caused by a high grease and oil content in the influent waste. The sludge is really quite old and fast settling and is typical of an extended aeration plant.

   d. Use slide to warn about relying solely on visual observations. They are only an indicator.

   e. Discuss the characteristics of the brush aerator.

V. Final Clarifier Observations (10 minutes)

   A. Final clarifier appearance helps identify potential problems. Some (many?) problems are caused by final clarifier design. Will look at both.

   B. Ask class "What does this final clarifier tell you?"

      1. This operator is doing a good job

      2. Spend time with him and find out how he does it (Note: study good operations to learn good operations.)

      3. Point out operator using blanket finder.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.8.40

Slide 179.2/11.8.40 is a photograph of an oxidation ditch showing the brush aerator. The mixed liquor is covered with thin, crisp white foam.

Use Slide 179.2/11.8.41

Slide 179.2/11.8.41 is a photo of the final clarifier which follows the aeration basin shown in Slide 179.2/11.8.40. The clarifier center well is filled with a thick grease layer.

Use Slide 179.2/11.8.42

Slide 179.2/11.8.42 is a word slide which reads:

"Final Clarifier Observations"

Use Slide 179.2/11.8.43

Slide 179.2/11.8.43 is a photograph of a final clarifier producing a beautiful clear effluent. Operator is measuring the sludge blanket depth.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
C. Notes on Final Clarifier Design Features 1. Point out major features of final clarifier mechanisms.	Use Slide 179.2/11.8.44 Slide 179.2/11.8.44 is a photo of an empty final clarifier showing sludge collection mechanism and the influent center well. Sludge collectors are located only in the center third of the tank radius.
2. Note that sludge collectors do not extend to the wall or into the center third of the clarifier. Possible problem is that sludge which settles in this region where there are no sludge collectors will stay on the bottom of the clarifier, not be removed, turn septic and float to the surface.	
3. Point out the problems near the clarifier wall: a. Clearance between the rake and the wall. b. Clearance between the scrapers and the floor. c. Long sludge travel time to nearest sludge collector. d. This leaves sludge which could turn septic and pop to the surface and overflow the clarifier. e. May correct by adding neoprene rubber to scrapers to serve as "squeegees".	Use Slide 179.2/11.8.45 Slide 179.2/11.8.45 is a close-up photo of the end of the rank mechanism of the clarifier shown in Slide 179.2/11.8.44 which shows clearance between the rake and the floor or wall of the final clarifier.
4. Point out that the sludge collectors on this mechanism extend the full length of the clarifier radius.	Use Slide 179.2/11.8.46 Slide 179.2/11.8.46 is a photo of a sludge collector mechanism with the suction collectors extending to cover the full radius of the clarifier.
5. The flexible extension on the end of this clarifier mechanism prevents solids accumulation at the wall.	Use Slide 179.2/11.8.47 Slide 179.2/11.8.47 is a photograph showing a sludge collection mechanism with a flexible rake extending to the clarifier wall.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
6. Use this slide to discuss rectangular final clarifiers. a. Flight mechanisms may not be efficient in moving sludge to the hopper. b. This clarifier could use some improvement in the scum baffle and scum removal systems.	Use Slide 179.2/11.8.48 Slide 179.2/11.8.48 is a photo of a rectangular final clarifier which is covered with a thick layer of scum near the effluent weirs.
D. Final Clarifier Obseravations Which Indicate Sludge Quality	
1. This is what we want to see at the final clarifier.	Use Slide 179.2/11.8.49 Slide 179.2/11.8.49 is a photo showing a well operated plant's final clarifier.
2. Ask class "What does this clarifier tell you?" a. The plant's in trouble. b. Not a lot about the cause of the problem. c. Appears that deflocculation or dispersed growth may have occurred. Could hint that there has been a toxic discharge.	Use Slide 179.2/11.8.50 Slide 179.2/11.8.50 is a photo of a rectangular final clarifier filled with a turbid milky looking final effluent.
3. Ashing a. Ask class "What does this final clarifier tell you about the plant?" b. This is called ashing. c. Usually associated with old, fast settling sludge, low F/M, long MCRT. d. Typical extended aeration plant effluent.	Use Slide 179.2/11.8.51 Slide 179.2/11.8.51 is a photo of the final effluent weirs. The final effluent is covered with ash.

LESSON OUTLINE

4. Clumping

   a. Ask class "What does this clarifier tell you?"

   b. This is called clumping.

   c. Probable cause is denitrification in the clarifier causing sludge to float. Sludge has been left in the final clarifier too long.

   d. Usually associated with old sludge, low F/M, long MCRT, fast settling.

   e. Solve clumping problem by

      1) Increasing return rate.

      2) Moving plant out of nitrification.

   f. Real problem is solids carry-over in final effluent. Note the problem caused by not haveing a scum baffle on the final clarifier.

   g. Ask class "What would it have meant if these clumps of sludge had been black?"

      1) Probably septic sludge floating to the surface.

      2) Phenomenon is called floating sludge.

      3) Caused by sludge remaining in the clarifier too long.

5. Straggler Floc

   a. Light, large, slow settling floc particles which are not captured and carried into the sludge blanket.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.8.52

Slide 179.2/11.8.52 is a photograph of a final clarifier showing large light brown clumps of sludge floating on the surface.

Use Slide 179.2/11.8.53

Slide 179.2/11.8.53 is a photograph showing clumps of sludge discharging to the final effluent. There is no scum baffle.

Use Slide 179.2/11.8.54

Slide 179.2/11.8.54 is a photograph showing billows of straggler floc near the final clarifier effluent weir.

LESSON OUTLINE

b. Usually occurs during the transition between too young a sludge and normal, good quality sludge.

c. Shallow clarifiers or other clarifier hydraulic problems will cause excess amounts of straggler floc to carry over into the effluent.

d. Solve problem by decreasing wasting to increase sludge age.

6. Billowing Sludge

    a. This is called billowing sludge.

    b. Sludge is a normal good settling sludge in the settleometer.

    c. Really a final clarifier hydraulics problem.

    d. Note that sludge particles appear discrete.

7. Bulking Sludge

    a. A sludge which settles very slowly or does not settle at all and does not concentrate is called a bulking sludge.

    b. Sludges which have an SVI > 200 are usually classified as bulking sludges.

    c. Bulking is a sludge quality problem.

    d. There are other causes of slow settling such as too much sludge (solids concentration too high) or clarifier hydraulics problems which can cause high clarifier sludge blankets and solids wash-out. This is not bulking although many

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.8.55
Slide 179.2/11.8.55 is a photo of sludge billowing up near the final effluent weir. The sludge particles appear discrete in the slide.

Use Slide 179.2/11.8.56
Slide 179.2/11.8.56 is a photo of a billow of bulking sludge breaking the surface of the final clarifier. The bulking sludge has a smooth, homogenous texture.

LESSON OUTLINE

operators refer to such problems in the generic class "bulking".

e. Note the homogenous, smooth appearance of the bulking sludge shown in Slide 179.2/11.8.56 as contrasted to the more granular texture of the billowing sludge shown in Slide 179.2/11.8.55.

f. Note that bulking sludges often produce excellent effluents but the problem is to keep the sludge in the final clarifier as shown by Slide 179.2/11.8.57.

g. Bulking sludges produce very small volumes of supernate very slowly.

h. Bulking is usually associated with a high F/M, low MCRT, high MLSS RR and short aeration basin detention time or short sludge aeration time.

i. Corrective actions are:

   1) Reduce return sludge flow rate.

   2) Decrease wasting to increase solids inventory.

   3) Use sludge reaeration.

j. Ask class to explain why return rate is reduced rather than increased to cure a bulking problem.

   1) Increasing return increases the hydraulic load on the clarifier and can cause solids wash-out.

   2) Decreasing return increases the clarifier sludge detention time allowing more time for settling and concentration and permitting

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.8.57

Slide 179.2/11.8.57 is a photo showing a high sludge blanket only 6 inches below the final clarifier effluent weir. This high blanket is caused by sludge bulking.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
return of a more concentrated sludge.	
3) Decreasing return increases aeration detention time allowing more time to stabilize the waste.	
k. Tell class that bulking will be discussed in more detail in the lesson on Final Clarifier Settling Problems.	Refer to Unit 11, Lesson 12, Final Clarifier Settling Problems.
VI. Trainee Problem Solving (15 minutes)	Use Slide 179.2/11.8.58 Slide 179:2/11.8.58 is a blank
A. Instructions to instructor for presenting three (3) problems to the class	Note: Problems are to be solved by preselected groups of four students.
1. Each problem is shown by using 2 slides that were used originally in subdivision 2. For each problem, the instructor reads the problem statement while showing the slides. Each trainee group should:	
a. Identify the problem	Note: Answer sheets are not provided.
b. Determine the likely cause	
c. Offer alternative solutions	
2. The instructor is given additional information with which to answer questions. Provide additional information to the class only when requested. Part of the exercise is for the class to identify what additional data is needed to analyze the problem and to obtain needed data.	
3. Stress that each group should approach the problems by applying the *Process of Troubleshooting*.	
4. Allow about 4 minutes for each problem.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
5. Solutions will be discussed after the three problems have been presented.	
B. Problem 1	
1. Problem Statement	
a. The aeration tanks of a 40 MGD conventional activated sludge plant look like this. The plant has the capability to return sludge in the range of 10 to 100% of influent flow.	Use Slide 179.2/11.8.59 Slide 179.2/11.8.59 is a photograph showing an aeration tank covered with billowing white foam.
b. The final clarifiers look like this. There are eight clarifiers, each with a separate return sludge pump.	Use Slide 179.2/11.9.60 Slide 179.2/11.8.60 is a photograph showing the final clarifier with a high bulking sludge blanket.
2. Additional Information	
a. F/M = 0.6	
b. Settling: 5 minutes 950 30 minutes 750 60 minutes 580	
c. Q = 40 MGD	
d. MLSS - 1,200 mg/l	Use Slide 179.2/11.8.61 Slide 179.2/11.8.61 is a blank.
e. RAS = 4,200 mg/l	
f. Reaeration is possible	
g. Return rate = 40%	
C. Problem 2	
1. Problem Statement	
a. This is a 1 MGD plant which can return sludge from 20 to 70% of influent flow rate.	Use Slide 179.2/11.8.62 Slide 179.2/11.8.62 is a photograph showing an aeration tank covered with thick gelatenous foam.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. There is only one final clarifier and it looks like this.	Use Slide 179.2/11.8.63 Slide 179.2/11.8.63 is a photograph of a final clarifier with sludge clumps floating on the surface.
2. Additional Information:	
a. MCRT = 14 days	
b. F/M = 0.13	Use Slide 179.2/11.8.64 Slide 179.2/11.8.64 is a blank
c. MLSS = 4,200 mg/l	
d. RAS = 12,600 mg/l	
e. Settling: 5 minutes 630 30 minutes 360 60 minutes 330	
f. There has been no sludge wasted in 7 days	
D. Problem 3	
1. Problem Statement	
a. This is an extended aeration plant with a design flow of 0.5 MGD	Use Slide 179.2/11.8.65 Slide 179.2/11.8.65 is a photograph showing an oxidation ditch brush aerator with crisp white foam.
b. The final clarifier looks like this	Use Slide 179.2/11.8.66 Slide 179.2/11.8.66 is a photograph showing a final clarifier with an ashing problem. Otherwise, the effluent looks pretty good.
2. Additional Information:	
a. MCRT = 15 days	
b. F/M = 0.07	
c. Q = 0.3 MGD	Use Slide 179.2/11.8.67 Slide 179.2/11.8.67 is a blank

d. RAS = 3,480 mg/l

e. MLSS = 2,400 mg/l

f. % RAS = 160%

g. Settling:
 5 minutes 405
 30 minutes 140
 60 minutes 115

E. Problem Answers - after about 12 minutes, have class provide solutions to problems 1 to 3. Seek agreement to arrive at a common answer for each case.

1. Problem 1 - This is a case of young sludge, low solids inventory and bulking.

2. Problem 2 - This is a case of an old sludge, high solids inventory and denitrification in the final clarifier.

3. Problem 3 - This is a sludge with grease and oil, that may look like a young sludge. (It settles much faster.)

VII. Lesson Summary

A. Visual inspection provides many clues to possible problems.

B. Flow rates should be noted and recorded.

1. Primary effluent flow

2. Return sludge flow

3. Waste sludge flow

4. Air flow to aeration

C. Aeration basin observations include:

1. Foam color

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

2. Foam quantity
3. Foam texture

D. Final clarifier observations include:

1. Surface appearance
2. Blanket appearance
3. Blanket depth

E. Visual observations are only clues to possible problems. They must be confirmed with laboratory test data.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 9: Case History: Pullman Treatment Plant

Lesson 9 of 14 lessons — Recommended Time: 50 minutes

Purpose: The purpose of this lesson is to provide trainees an opportunity to apply information presented in Unit 11, Lessons 1 - 8 to problem solving in an activated sludge treatment plant. Trainees apply what they have learned to solution of a case history problem situation.

Trainee Entry Level Behavior: The trainee should have achieved the learning objectives specified for Unit 11, Lessons 1 - 8 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. Using information provided about the operation of an activated sludge treatment plant, describe the operating problems at the activated sludge treatment plant and identify the problem cause as extreme variations in loading.
2. Using data provided, the *Trainee Notebook* and class notes, analyze and troubleshoot process control problems at an activated sludge plant subjected to extreme variations in loading.
3. Identify practical modifications in return activated sludge system and in aerator operating modes that may be implemented to control an activated sludge process subject to extreme variations in applied load.
4. Describe the use of Fed Sludge and MLSS respiration rates as a basis for process control decision making in an activated sludge process subjected to extreme variations in applied load.

Instructional Approach: Trainee problem solving while working in groups of four trainees.

Lesson Schedule: The 50 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 10 minutes	Description of Pullman Problem
10 - 50 minutes	Student Analysis of Problem

Note: Lesson 9 should be scheduled as the last instructional hour of the day with Lesson 10 scheduled as the first hour the following day. This gives the class "thinking time."

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T11.9.1 - T11.9.7 , "The Pullman Treatment Plant - Situation and Data."

2. *Trainee Notebook*, page T11.9.8 , "Pullman Troubleshooting Problem - Answer Sheet."

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 11.9.1 - 11.9.6 , Unit 11, Lesson 9.

2. *Trainee Notebook*, pages T11.9.1 - T11.9.7 , "The Pullman Treatment Plant - Situation and Data."

3. *Trainee Notebook*, page T11.9.8 , "Pullman Troubleshooting Problem - Answer Sheet."

Instructor Materials Recommended for Development: None

Additional Instructor References:

1. Johnson, D. S., S. K. Bhagat and T. Asano, "Operational Control of an Activated Sludge Process by Biomass Respiration Rates," presented at the 44th Annual Pacific Northwest Pollution Control Association Meeting, Portland, Oregon (November 2 - 4, 1977) (Copy included with lesson plan)

2. Johnson, D. S., S. K. Bhagat, T. Asano and J. E. Ongerth, "Operation of an Activated Sludge Process Using Biomass Respiration Rates to Accommodate Fluctuating Hydraulic and Organic Loads," Final Report, Department of Civil and Environmental Engineering, Washington State University, Pullman, Washington (July, 1976).

3. Joyce, R. J., C. Ortman, and C. Zickefoose, "Optimization of an Activated Sludge Plant Using TOC, Dissolved Oxygen, Respiration Rate and Sludge Settling Volume Data," presented at the WWEMA Ind. Water and Pollution Conference, Detroit, Michigan (April, 1974).

4. Benefield, L. D., C. W. Randall and P. H. King, "Process Control by Oxygen-Uptake and Solids Analysis," *Journal Water Pollution Control Federation*, 47, 2498 (October, 1975).

Classroom Set-Up: As specified in Unit 11, Lesson 7.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	It is recommended that this problem be given as the last hour of the training day. The class findings should be discussed as the first session on the following day. This scheduling gives the class additional thinking time to develop innovative solutions to the problem. The course agenda should be modified as necessary to accomplish this but THIS LESSON MUST FOLLOW LESSON 7.
	Review the paper by Johnson, et al which is included in the *Instructor Notebook* for additional background information about the problem.
	Circulate about the classroom answering questions from the work groups. Be careful not to give away the solution to the problem but guide the class toward the solution as appropriate.
	There are several acceptable solutions to the problem. The solution implemented at Pullman is effective but should not be viewed as an exclusive or unique answer to the operational problems at Pullman.
I. Description of the Problem and the Pullman Treatment Plant (10 minutes)	Refer class to *Trainee Notebook*, pages T11.9.1 - T11.9.3 for a statement of the Pullman Problem.
A. Operational History	
1. Have trainees read *Trainee Notebook*, pages T11.9.1 - T11.9.3.	
2. Answer questions on plant background and history.	

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

B. Flow diagram - have trainees briefly review:

1. Page T11.9.4 - Simplified Flow Diagram

2. Page T11.9.5 - Facts about the Plant

C. Influent Flow Pattern

1. Have trainees review page T11.9.6.

2. Describe causes for plant upset based on flow variations, as related to trainee activities.

   High flows occur on days of:

   a. Rainy week days

   b. Home football games

   c. Snow melt

3. On an annual basis, the most difficult time is from September through January with vacations and highly variable weather.

D. Comparison of BOD Removal

1. Refer to page T11.9.7 to compare the November, 1974 performance with the November, 1975 performance.

2. Note that in November, 1974, final effluent BOD averaged around 50 mg/l.

3. Troubleshooting assistance in October-November, 1975 brought BOD levels below 30 mg/l.

E. The problem for the trainees, and to be discussed by the instructor, is how the improvement was accomplished.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
II. Trainee Analysis of Pullman Problem (40 minutes)	
A. Have trainees work in pre-selected groups of four (4) persons.	Separate break-out rooms for work groups should be provided.
B. Have trainee groups use the answer sheet provided, page T11.9.	
III. Dismiss class at end of the day. Problem will be discussed as first session next morning.	

44th Annual
Pacific Northwest Pollution Control
Association Meeting

Hilton Hotel
Portland, Oregon

November 2-4, 1977

OPERATIONAL CONTROL OF AN ACTIVATED SLUDGE PROCESS BY BIOMASS RESPIRATION RATES

By

Danny S. Johnson
Assistant Engineer
Stevens, Thompson & Runyan, Inc.

Surinder K. Bhagat
Professor, Head of Environmental Engineering
Washington State University

Takashi Asano
Department of Civil and Environmental Engineering
Washington State University

ABSTRACT

Title: Operational Control of an Activated Sludge Process by Biomass Respiration Rates

By: Danny S. Johnson, Surinder K. Bhagat,
Takashi Asano

The fluctuations in both hydraulic and organic loadings lead to highly varying food to microorganism ratio, hydraulic detention time, and sludge age in the activated sludge process that in turn are responsible for the poor treatment performance at the Pullman, Washington Wastewater Treatment Plant. The operation of an activated sludge process which is subjected to fluctuating loadings requires operational flexibility with rapid monitoring of influent wastewater and process control adjustments.

To provide this operational flexibility, the existing activated sludge plant was modified to install additional return sludge discharge points for each aeration tank. A change in the operational mode permits the variation in the length of time activated sludge undergoes aeration, and thus controls microbial metabolism of wastewater. The respiration rates of the activated sludge were used to optimize the operation of a full-scale activated sludge plant. The respiration rate of the aeration tank effluent was proved to be an important operational parameter. The optimum range of respiration rates of the activated sludge as it leaves the aeration rank was found to be between 12 and 20 mg O_2/hr/g MLSS and, by using this control method, the activated sludge process was able to produce a monthly average BOD_5 of 13 mg/ℓ and SS of 24 mg/ℓ, respectively.

Although activated sludge processes have been widely used to provide secondary treatment of municipal and industrial wastewaters throughout the world, many activated sludge plants often fail to provide the intended treatment performance due mainly to the highly fluctuating hydraulic and organic loadings. These fluctuating loads may be caused by intermittent discharge of industrial wastes, by migrating populations which comprise a substantial fraction of the relatively small community, and by excessive storm water infiltration and inflow.

The conventional activated sludge plant at Pullman, Washington is subjected to wide load fluctuations caused by a migrating student population as well as excessive storm water infiltration and inflow. Washington State University students who leave Pullman during holiday and vacation periods comprise approximately fifty (50) percent of the sewered population. Accordingly, the fluctuations in both hydraulic and organic loadings lead to highly varying food to microorganism ratio (F/M), hydraulic detention time, and sludge age that in turn are responsible for the poor treatment performance at the Pullman Wastewater Treatment Plant.

As shown by Keyes and Asano[1], the effluent substrate concentration, S_e, from an activated sludge process is a direct function of either food to microoganism ratio, U, or sludge age, θ_c. Furthermore, controlling either U or θ_c in an activated sludge process will directly control the process treatment efficiency, E. It is important, therefore, to maintain the optimum values of these parameters as closely as possible at all times. To maintain a required sludge age is a difficult operational undertaking, especially under highly fluctuating load conditions. However, the F/M ratio can be controlled if a rapid determination of influent substrate concentration is made, and the process is adjusted as required to keep up with the load variations to the activated sludge process. An activated sludge process control method proposed by Benefield *et al*[2]. used respiration rates and suspended solid levels as primary control parameters, and the sludge wasting was used as the only control variable. In this method, if the analysis scheme called for a prolonged period of no sludge wasting from the activated sludge system, it would mean that the F/M ratio had become relatively large and this would lead to sludge with poor settling characteristics and eventual loss in the undesirably high F/M ratio, thus eventual process failure would result. This fact is considered to be the main drawback of the method and, without actual plant operating data, it is difficult to assess the system stability by using this control scheme.

Joyce *et al.*[3] on the other hand used the F/M ratio to control an activated sludge process that was subjected to intermittent industrial waste discharges. The rapid measurement of the incoming wastewater strength by total organic carbon analysis made it possible to regulate the rate of sludge return to match the incoming loads. In this way the F/M ratio was maintained at a constant level. Ludzack[4] has proposed a method for monitoring influent and effluent wastewater biomass respiration rates. The ratio of respiration rates of the biomass in influent wastewater to those of the biomass in effluent was termed the load ratio (LR), and it was suggested that the optimum treatment performance occurred when the LR values are between 2 and 4. Unfortunately, an operational method or variable which may be used to control the LR values within the suggested range was not reported.

ACTIVATED SLUDGE PROCESS CONTROL PROCEDURE

The foregoing discussions provided the basis for the study that led to the development of a simple and reliable control method for the prototype activated sludge treatment plant under highly fluctuating hydraulic and organic loads encountered at the Pullman Wastewater Treatment Plant. The operation of the activated sludge process which is subjected to fluctuating hydraulic and organic loadings, as shown in Figures 1 and 2, requires operational flexibility with rapid process monitoring and control adjustments. To provide this operational flexibility, the existing activated sludge plant was modified by installing additional return sludge discharge points for each aeration tank. Figure 3 shows the existing points of return sludge prior to modification, and Figure 4 shows six (6) multiple return sludge discharge points after modification. Thus, the modification provided nine (9) aerator operational modes as shown in Figure 5, which permitted the variation of activated sludge aeration time.

A change in the operational mode permits the variation in the length of time activated sludge undergoes aeration, and thus controls microbial metabolism of wastewater in the activated sludge process. To make successful process

1069

control during fluctuating load conditions, it is essential to provide a means of rapidly monitoring the strength of incoming wastewater. Obviously, the BOD_5 test does not satisfy this requirement, and an alternative to the BOD_5 must be used. Chemical oxygen demand and total organic carbon analyses are two of the alternative methods. However, most wastewater treatment plants do not have adequate personnel and facilities to perform these tests routinely. Hence, respiration rates which can be determined by the use of a simple dissolved oxygen meter were selected as indicators of incoming wastewater strength, wastewater treatability, and physiological conditions of biomass.

Existing Treatment System

For over 11 years the City of Pullman, Washington has been providing conventional activated sludge treatment to municipal wastewaters prior to their discharge into the South Fork of the Palouse River. Aeration of the mixed liquor suspended solids (MLSS) is accomplished in two (2) parallel 0.35 million gallon (1,325 m^3) aeration tanks. Mixing and aeration are provided by three submerged turbine and sparge ring aerators in each tank. Air is supplied by three 600 cubic feet per minute (17 m^3/min) blowers.

Each basin is provided with a single inlet for primary treated wastewater, and a single introduction point for the return activated sludge, located in close proximity to the primary effluent inlet. Thus, the only possible operational controls available prior to the study were the variation of the return sludge flow rates and the activated sludge wasting rate. Effluent from the two (2) aeration tanks is conveyed by gravity to a single 0.35 million gallon (1,325 m^3) final clarifier. The settled activated sludge is returned to the aeration tanks by two (2) variable discharge centrifugal pumps. Excess activated sludge is wasted from the return sludge line to the primary clarifier via the plant influent pumping station. Figure 6 shows the flow diagram of the Pullman Wastewater Treatment Plant with sample locations for this study.

Two major wastewater flow regimes at the Pullman Wastewater Treatment Plant are: the total population flow regime (high flow), and the vacation flow regime (low flow). The high flow regime occurs during the regular academic sessions of Washington State University when students, faculty, and staff are present in the city. The majority of this flow pattern occurs during the wet weather season. The low flow regime occurs during the vacation and holiday periods of the University at which time the population of the city may decrease by as much as seventy (70) percent.

Operation of the wastewater treatment facilities during the high flow period requires the use of the maximum activated sludge process capacity available. Peak flows greater than 6.5 mgd (24,603 m^3/day), maximum design capacity, bypass the plant because of the hydraulic limitations of the treatment facility. Mixed liquor suspended solids of approximately 1,000 mg/ℓ are maintained with an approximate return activated sludge flow rate of thirty (30) percent of the daily average flow. Low flow periods result in both decreased flows and organic loads, and hence the operational practice has been to use only one aeration tank, and dewater the other to conserve energy. The practice of dewatering one of the two aeration tanks results in the loss of approximately thirty-three (33) percent of the biomass which later leads to a high F/M ratio when the basin is placed back into service under high loading conditions.

Experimental Methods

The study was conducted from October 6, 1975 to January 18, 1976 at the Pullman Wastewater Treatment Plant, Pullman, Washington. The study period included two University vacation periods, namely Thanksgiving vacation from November 21 to December 1, and Christmas vacation from December 20 to January 5. Daily records were kept of the plant influent flow rate and of the return activated sludge flow rate. Operational parameters measured and recorded included: MLSS concentration, return sludge concentration, BOD_5 of the process influent and effluent, sludge volume index (SVI), and sludge respiration rates.

Both MLSS and return sludge concentrations were determined by using Whatman No. 2 filter paper and by the centrifugal method as described by Hegg and Burgeson[5]. Respiration rates were determined three or four times daily on three biomass mixtures. The first mixture tested at each sampling period was the aeration tank effluent. The second mixture contained primary effluent and return activated sludge. Final clarifier effluent and return activated sludge comprised the third mixture. Samples were collected at the points shown in Figure 6. The proportion of return activated sludge used was calculated by the following formula:

$$RAS = \frac{V_t \alpha}{1 + \alpha}$$

in which

RAS = return activated sludge required, mℓ
v_t = total volume of sample being prepared, mℓ
α = recirculation ratio, Q_r/Q

This provided a mixture of wastewater and activated sludge biomass in the proportions in which they were being added to the actual aeration tanks. The method used to determine the respiration rate of the biomass in each mixture was the one recommended by Ludzack[4]. Hydrolab IIA dissolved oxygen meter was used for the DO determinations. Throughout the experiment the decrease of DO in the container with time was recorded, and the change in DO per minute (ΔDO/min) was determined. When the ΔDO/min value became constant, it was recorded as the ΔDO/min value for that sample.

The respiration rate, $\overline{R}$, of the aeration tank effluent taken from the aeration tank launder is denoted as $\overline{RAM}$. Similarly, when the wastewater in the mixture is primary effluent, $\overline{R} = \overline{RAP}$, and for the mixture using final clarifier effluent, $\overline{R} = \overline{RAF}$. These respiration rates can be determined in approximately thirty (30) minutes, thus providing a rapid means for process monitoring and control. The detailed methods of oxygen uptake and respiration rate determination were reported elsewhere[6].

ANALYSIS OF ACTIVATED SLUDGE PROCESS PERFORMANCE

Control of an activated sludge process which is subjected to wide variations in hydraulic and organic loadings requires frequent monitoring and process adjustments to maintain a high quality effluent. Thus, process flexibility and operational adaptability are essential to provide the optimum treatment conditions in the activated sludge process. Widely used operational control methods for the activated sludge process include: (1) control to a constant sludge age, (2) control to a constant F/M ratio, and (3) control to a constant MLSS concentration. These control methods, however, are generally difficult to attain in highly fluctuating load conditions due mainly to the lack of available flexibility required to make operational adjustments in response to load variations. An activated sludge process which never approaches steady-state operating conditions requires the use of every control method available to minimize the impact of loading variations upon the biomass.

Basis of Rapid Process Monitoring and Control

The amount of time required by activated sludge microorganisms to adequately stabilize wastewater will vary with type and strength of wastewater. The modifications of the return sludge line as shown in Figures 3 and 4 provided the physical flexibility to vary the biomass aeration time. The modes of operation, as shown in Figure 5, allowed the use of various portions of the aeration tank capacity. Thus, a change in mode varied the length of time the activated sludge underwent aeration and controlled the time of microbial metabolism of the wastewater.

Substrate removal kinetics in an activated sludge process are widely considered to be first order and, therefore, the metabolic rate of activated sludge microorganisms will vary with substrate concentration. On the other hand, the respiration rate of activated sludge microorganisms will vary directly with their metabolic rate[7]. This means that high respiration rates indicate high metabolic rates, and similarly low respiration rates indicate low metabolic rates. Joyce et al[3]. reported that the optimum respiration rates of the activated sludge as it leaves the aeration tanks is between 12 and 20 mgO_2/hr/g MLSS, on the basis of effluent BOD_5 requirements.

The respiration rate $\overline{RAM}$ values will dictate the time of aeration required for the optimum performance, and the operational mode changes can be used to attain this required aeration time. The range of respiration rates proposed by Joyce et al[3]. was used as a guideline for the process control at the Pullman Wastewater Treatment Plant. When the respiration rate was greater than 20 mgO_2/hr/g MLSS, the operational mode was changed to increase the aeration time of the biomass. Similarly, when the respiration rate of the biomass fell below 12 mg O_2/hr/g MLSS, the aeration time was decreased by changing the mode number.

Respiration rates will vary with type and strength of wastewaters as discussed previously, but they are also affected by other environmental factors. Ludzack[4] stated that, "A large increase in respiration rate means abundant acceptable feed under favorable conditions. A small increase means

1073

dilute feed, sick sludge, poorly acceptable feed, incipient toxicity, or unfavorable conditions." The $\overline{RAP}$ information obtained by the respiration rate analysis was used to adjust the rate of return sludge according to the incoming load fluctuations.

The return sludge flow rate should be varied in direct proportion to the influent wastewater strength and the influent wastewater flow rate, and indirect proportion to the return sludge SS concentration. Assuming that the mass ratio of BOD_5 applied to the activated sludge system to the returned activated sludge is constant, the following relationship among influent flow rate, return sludge flow rate, and return sludge SS concentration can be established:

$$K = \frac{Q\,\overline{RAP}}{Q_r X_r} \qquad (1)$$

in which

K = return constant

Q = influent flow rate (primary wastewater flow rate to aerators), mgd

Q_r = return activated sludge flow rate, mgd

$\overline{RAP}$ = respiration rate of primary effluent and return activated sludge, mgO_2/hr/g MLSS

X_r = SS concentration in the return sludge, mg/ℓ.

Rearranging Equation 1 yields Equation 2 which was used to calculate the rate of required return sludge flow:

$$Q_r = \frac{Q\,\overline{RAP}}{K\,X_r} \qquad (2)$$

The value of the return constant, K, representing the optimum performance, was determined by the trial and error method.

Respiration Rates and Process Performance

During the study periods, nine (9) operational mode changes were made in response to the changing respiration rates of the aeration tank effluent ($\overline{RAM}$ values) as shown in Figure 7. Referring to Figure 5, the operational modes used were respectively modes 0, 1, 2, 3A, 4A and 5A. During the Thanksgiving vacation, from November 21 to December 1, 1975, one of the aeration tanks was operated as a solid holding tank. From November 21 to November 27, the activated sludge process was operated in mode 3A. During this period the average $\overline{RAM}$

value was 9 mgO$_2$/hr/g MLSS, and the average total BOD$_5$ of the process effluent was 15 mg/ℓ. Mode 4A was used from November 27 to December 1 and total BOD$_5$ of the effluent was 13 mg/ℓ, and the $\overline{\text{RAM}}$ value averaged 6 mgO$_2$/hr/g MLSS.

At the end of Thanksgiving vacation, operation was changed to mode 2 to handle increased loading due to the return of the University students. The operational transition from mode 4A to mode 2 was made abruptly. A rapid snow melt and the returning students created a peak flow of 10 mgd (37,850 m^3/day) which caused wash-out of solids from the final clarifier for several hours, but this did not result in a biological process upset. The activated sludge process performed, overall, a smooth transition from the vacation low flow regime to the normal high flow regime. While in mode 2, from December 1 to December 20, the process produced an average total effluent BOD$_5$ of 14 mg/ℓ, and average total SS of 26 mg/ℓ, and the average $\overline{\text{RAM}}$ value was 10 mgO$_2$/hr/g MLSS.

At the beginning of the Christmas vacation period the activated sludge process was changed to mode 3A. The transition from the high flow regime to the low flow regime occurred without process upset. The activated sludge system was in mode 3A from December 20 to December 26. The $\overline{\text{RAM}}$ average was 9 mgO$_2$/hr/g MLSS, and the average effluent total BOD$_5$ was 15 mg/ℓ. A mode change to 5A was made on December 26 in an intentional attempt to increase the $\overline{\text{RAM}}$ to see if this would lead to degradation of the activated sludge process effluent quality. The system was operated in mode 5A from December 26 to January 4. The $\overline{\text{RAM}}$ did not increase, but continued to trend downward as a result of the unexpected decrease in influent BOD$_5$ loading. As the BOD$_5$ loading began to increase, the $\overline{\text{RAM}}$ values and the effluent total BOD$_5$ also began to increase. Average process parameters for this period of operation in mode 5A were: effluent total BOD$_5$ = 11 mg/ℓ and $\overline{\text{RAM}}$ = 9 mgO$_2$/hr/g MLSS.

As the process loadings continued to increase, the mode was changed to 4A. The end of Christmas vacation, on January 5, 1976, resulted in a sharp increase in the average influent loadings. The average influent loadings for the period from January 4 to January 8 were approximately fifty (50) percent greater than the loadings from the period from December 26 to January 4. This rapid increase in loading initiated an upward trend of the $\overline{\text{RAM}}$ and resulted in a $\overline{\text{RAM}}$ value of 20 mgO$_2$/hr/g MLSS on January 8. The corresponding effluent BOD$_5$ was 27 mg/ℓ, which was a sharp increase from the day before. Because $\overline{\text{RAM}}$ had reached the decision point of 20 mgO$_2$/hr/g MLSS, the mode was changed to 3A on January 9. The $\overline{\text{RAM}}$ values remained high for 5 days, and the corresponding effluent BOD$_5$ values exceeded 30 mg/ℓ twice.

Mode 3A was used from January 9 to the end of the study period, January 18. After January 14, the $\overline{\text{RAM}}$ values dropped to an average of 14 mgO_2/hr/g MLSS, and the effluent total BOD_5 average for the same period was 14 mg/ℓ.

An activated sludge process upset began on January 8 and lasted 5 days. It was characterized by sludge bulking in the final clarifier on January 8, and a 5-day average effluent BOD_5 of 29 mg/ℓ. The process upset was initiated because the additional biomass and aeration tank capacity were not used to buffer the transition between the low flow regime and the high flow regime. Tabulation of the average process parameters for each mode of operation is shown in Table 1.

The use of respiration rates to monitor and to control the activated sludge process has been demonstrated in this study. A significant decrease in effluent BOD_5 was shown in Figure 7, and, correspondingly, the substantial increase in BOD_5 removal efficiency in the activated suldge process is shown in Figure 8.

As discussed earlier, the respiration rate of the aeration tank effluent ($\overline{\text{RAM}}$) was used as a guide for the necessary change of mode of operation, and it was proved to be a valuable parameter for controlling the activated sludge process. Figure 9 shows the relationship between the $\overline{\text{RAM}}$ values and the effluent total BOD_5. The dotted lines were drawn to include seventy-seven (77) percent of the data points. The equation for the line of best fit was determined by the linear regression analysis of the data points using a Wang 370 computer. The use of Figure 9 is restricted in the lower limit by low $\overline{\text{RAM}}$ values which may lead to solid-liquid separation difficulties in the final clarifier such as pin-floc formation, and in the upper limit by effluent BOD_5 discharge requirements.

The selection of the operational range for $\overline{\text{RAM}}$ based solely upon effluent BOD_5 considerations must be examined in two plant flow regimes. For a high flow regime with a low influent BOD_5, for example, of 100 mg/ℓ, the treated effluent must contain less than 15 mg/ℓ BOD_5 if the eighty-five (85) percent removal efficiency is imposed for the activated sludge process. From Figure 9 the desirable range of $\overline{\text{RAM}}$ values are from 7 to 16 mgO_2/hr/g MLSS and the median value 11 mgO_2/hr/g MLSS. Similary, for low flow regime and assuming 60 mg/ℓ influent BOD_5, the process effluent must be less than 9 mg/ℓ BOD_5 in order to meet the discharge permit. To attain this requirement the $\overline{\text{RAM}}$ values must be somewhere between 3 and 11 mgO_2/hr/g MLSS and the median value 7 mgO_2/hr/g MLSS. Operational control over the range of 5 to 11 mgO_2/hr/g MLSS was possible at the Pullman Activated Sludge Plant, but a $\overline{RAM}$ value much lower than 7 mgO_2/hr/g MLSS may lead to solid-liquid separation difficulties in the final clarifier.

The relationship between respiration rates of the aerator effluent ($\overline{RAM}$) and the activated sludge settling characteristics (SVI) is shown in Figure 10. As expected in most sludge settling tests, correlation was relatively poor. It should be noted, however, that even though the SVI values remained relatively high, marked improvement in solid-liquid separation occurred in the clarifier.

The dye tracer study of the Pullman Activated Sludge Plant showed that a change in the mode of operation was reflected in the length of aeration time of the biomass. The time concentration curve shown in Figure 11 indicates that mixing in the aeration tank is intense but not enough to provide a completely mixed reactor. The fact that the mixing regime in the tank is not completely mixed has provided additional operational flexibility with respect to the mode of operation which allowed the successful treatment of fluctuating loadings at the Pullman Wastewater Treatment Plant.

Ludzack[4] indicated that the load ratio (LR) was an important process performance indicator and the optimum range being from 2 to 4. However, in this study both the effluent BOD_5 and BOD_5 removal efficiency showed no apparent correlation to LR which is the ratio of $\overline{RAP}$ to $\overline{RAF}$ in this study.

SUMMARY AND CONCLUSIONS

The full-scale Pullman Activated Sludge Plant was successfully operated using the biomass respiration rate as a control parameter while being subjected to wide fluctuations in both hydraulic and organic loadings. The activated sludge process was able to produce a monthly average BOD_5 of 13 mg/ℓ and SS of 24 mg/ℓ, respectively. The operational control method by biomass respiration rates should have wide application for activated sludge process monitoring and control since the required equipment, including a DO meter, are, in most cases, already possessed by the treatment plant, and process flexibility that many plants have but are not using.

The more specific conclusions derived from this study are as follows:

1. Respiration rate of the aeration tank effluent ($\overline{RAM}$ value) was proved to be an important operational parameter in controlling the activated sludge

process for the optimum performance. $\overline{\text{RAM}}$ measurement is rapid and easy, and requires commonly available laboratory equipment. The operational $\overline{\text{RAM}}$ values can be obtained from Figure 9 at given BOD_5 discharge requirements.

2. Respiration rate of the biomass in primary effluent ($\overline{\text{RAP}}$ value) was used to approximate incoming wastewater strength and proved to be useful in determining the amount of return sludge required as shown in Equation 2. It is, however, cautioned that $\overline{\text{RAP}}$ value is not to be taken as a direct measurement of wastewater strength because it is a respiration rate and, hence, is dependent on many other environmental factors besides a substrate concentration.
3. In this study $\overline{\text{RAM}}$ and $\overline{\text{RAP}}$ measurements were used to successfully adjust the process to cope with widely fluctuating hydraulic and organic loading conditions.
4. Prior to use of the procedures demonstrated in this study, the plant performance was inadequate to meet the effluent guidelines. The final effluent BOD_5 average for 3 months was 50 mg/ℓ, while the maximum allowable is approximately 20 mg/ℓ. After applying the procedures developed in this study, the final effluent BOD_5 was brought down to within discharge permit limits (Figure 7).
5. It has been demonstrated that, for accomplishing effective treatment, it is essential to have adequate flexibility available in the physical system to enable the operator to make appropriate process adjustments as required to respond to the varying incoming hydraulic and organic loads. The $\overline{\text{RAM}}$ and $\overline{\text{RAP}}$ measurement tools as applied in this study can be used to determine the type of process adjustments required.
6. It is recommended that future studies be directed toward investigating the relationship between wastewater strength, $\overline{\text{RAP}}$, sludge conditioning, and F/M ratio. The effect of sludge age on the parameters including $\overline{\text{RAM}}$ and $\overline{\text{RAP}}$ should also be investigated. In this study, no good correlation between $\overline{\text{RAM}}$ and SVI was observed. A better indicator of solid-liquid separation in the clarifier other than SVI is warranted.

References

1. Keyes, T. W., and Asano, T., "Application of Kinetic Models to the Control of Activated Sludge Processes," Jour. Water Poll. Control Fed., 47, 2574 (Nov. 1975).

2. Benefield, L. D., Randall, C. W., and King, P. H., "Process Control by Oxygen - Uptake and Solids Analysis," Jour. Water Poll. Control Fed., 47, 2498 (Oct. 1975).

3. Joyce, R. J., Ortman, C., and Zickefoose, C., "Optimization of an Activated Sludge Plant Using TOC, Dissolved Oxygen, Respiration Rate and Sludge Setting Volume Data," Presented at the WWEMA Ind. Water and Poll. Conference, Detroit, Michigan (April 1974).

4. Ludzack, F. J., "Dissolved Oxygen Analysis-Activated Sludge Control Testing," EPA Research Training and Technical Support, NO. XT-43, (June 1971).

5. Hegg, B. A., and Burgeson, J. R., "An Integrated Approach to Control Testing and Basic Kinetics," Presented at 47th WPCF Conf., Denver, Colorado (Oct. 1974).

6. Johnson, D. S., Bhagat, S. K., Asano, T., and Ongerth, J. E., "Operation of an Activated Sludge Process Using Biomass Respiration Rates to Accomodate Fluctuating Hydraulic and Organic Loads," Final Report, Dept. of Civil and Env. Engr., Washington State University, Pullman, Washington (July 1976).

7. Stanier, R. Y., Doudorff, M., and Adelberg, E. A., The Microbial World, 3rd Ed., Prentice-Hall, Inc., Englewood Cliffs, New Jersey (1970).

List of Figures

Fig. 1. BOD_5 and Influent Flow Fluctuations for November 18 and 19, 1975; High Flow Regime, Pullman Activated Sludge Plant.

Fig. 2. BOD_5 and Influent Flow Fluctuations for November 24 and 25, 1975; Low Flow Regime, Pullman Activated Sludge Plant.

Fig. 3. Points of Activated Sludge Return Prior to Modification.

Fig. 4. Points of Activated Sludge Return After Modification.

Fig. 5. Mode of Operation with the Portion of Aeration Tank Capacity Used, and Return Activated Sludge Discharge Points.

Fig. 6. Flow Diagram of Pullman, Washington, Wastewater Treatment Plant.

Fig. 7. Improvement in Activated Sludge Process Performance as a Result of Biomass Respiration Rate Control, Pullman Wastewater Treatment Plant.

Fig. 8. BOD_5 Removal Efficiency in the Activated Sludge Process (Based on Primary Effluent to Final Effluent).

Fig. 9. Relationship between $\overline{RAM}$ values and Effluent Total BOD_5 (Daily Average Values).

Fig. 10. Relationships between $\overline{RAM}$ and SVI (Daily Average Values).

Fig. 11. Time Concentration Curve for the Aeration Tank (Rhodamine WT).

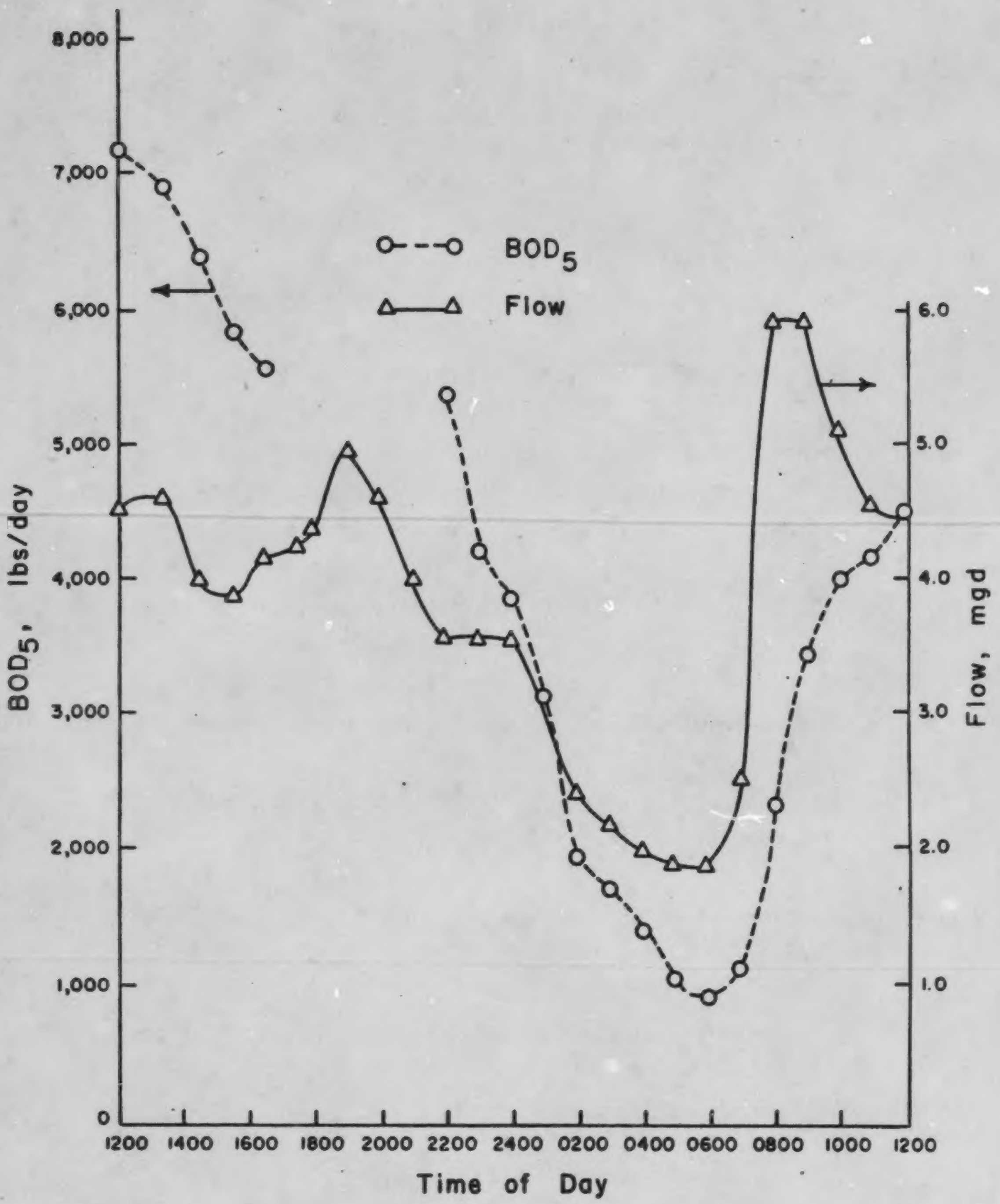


Fig. 1 BOD_5 and Influent Flow Fluctuations for November 18, and 19, 1975; High Flow Regime, Pullman Activated Sludge Plant

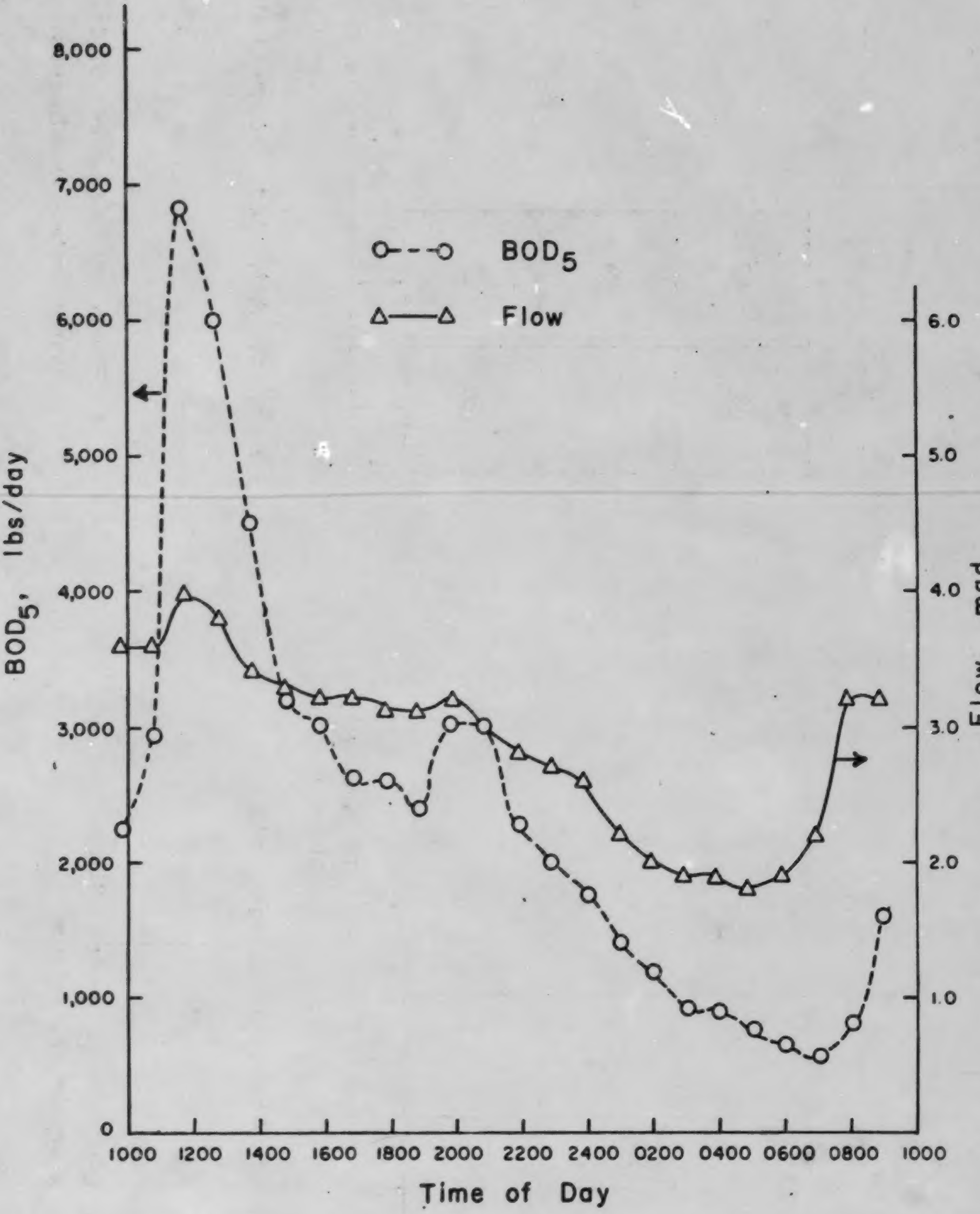


Fig. 2 BOD$_5$ and Influent Flow Fluctuations for November 24, and 25, 1975; Low Flow Regime, Pullman Activated Sludge Plant

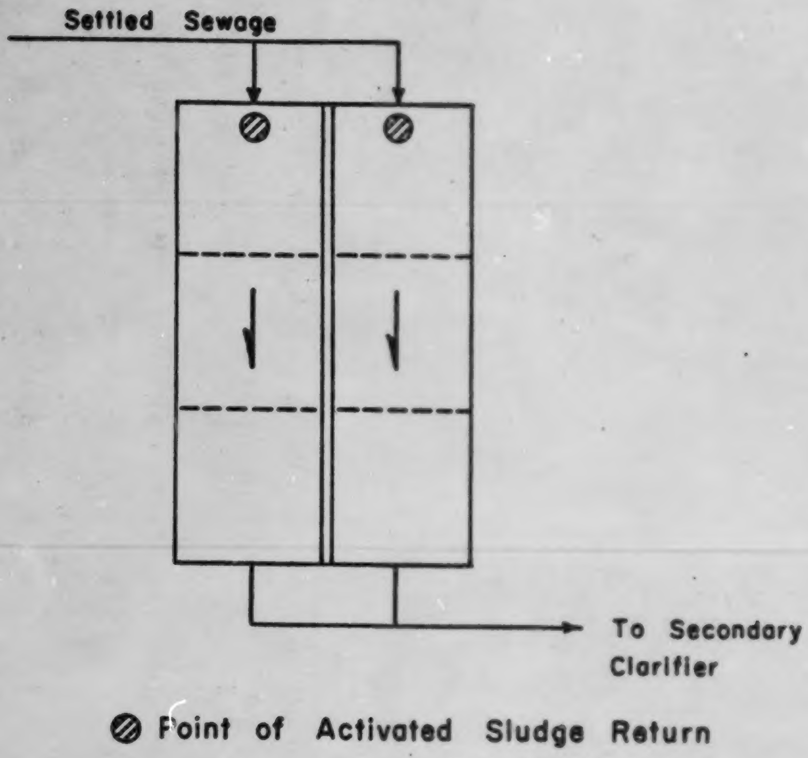


Fig. 3 Points of Activated Sludge Return prior to Modification

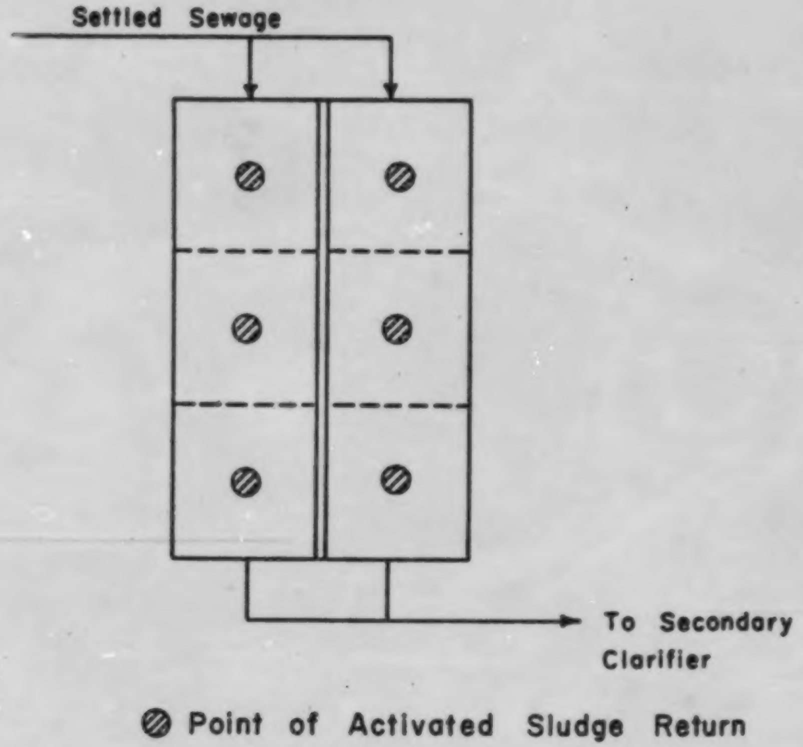


Fig. 4 Points of Activated Sludge Return after Modification

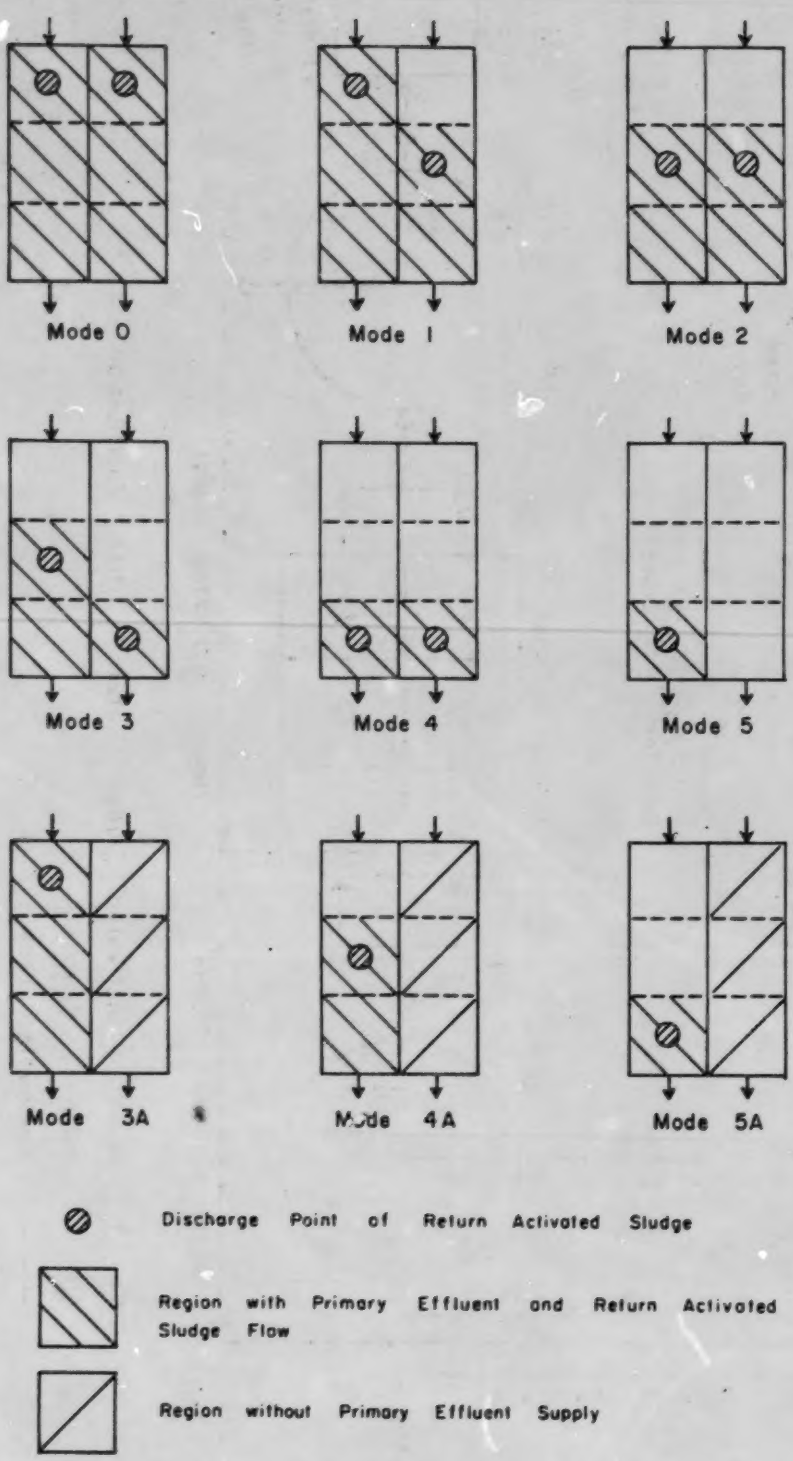

Mode 0
Mode 1
Mode 2
Mode 3
Mode 4
Mode 5
Mode 3A
Mode 4A
Mode 5A
Discharge Point of Return Activated Sludge
Region with Primary Effluent and Return Activated Sludge Flow
Region without Primary Effluent Supply

Fig. 5 Modes of Operation with the Portion of Aeration Tank Capacity used, and Return Activated Sludge Discharge Points

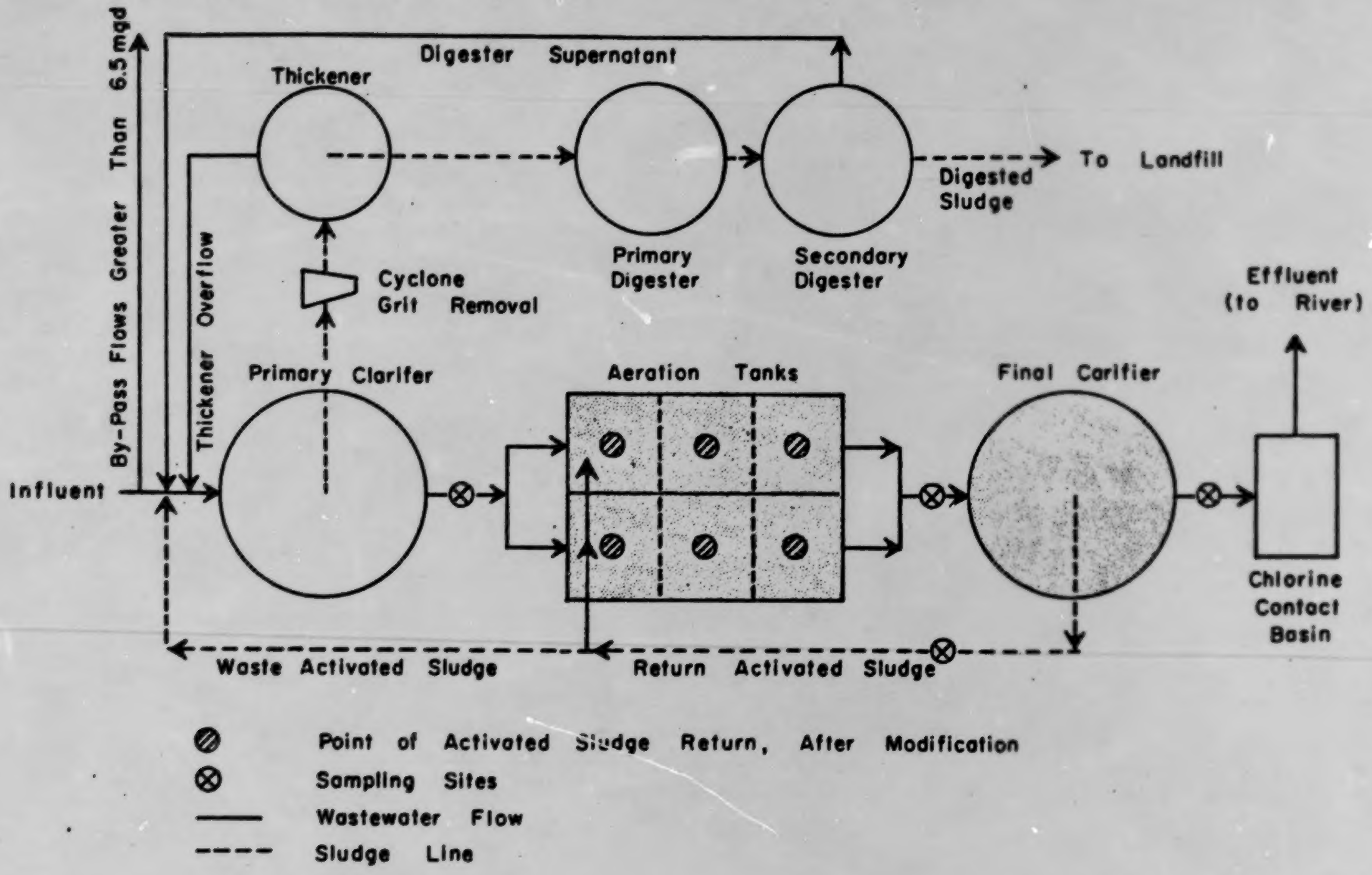


Fig. 6 Flow Diagram of Pullman, Wash., Wastewater Treatment Plant

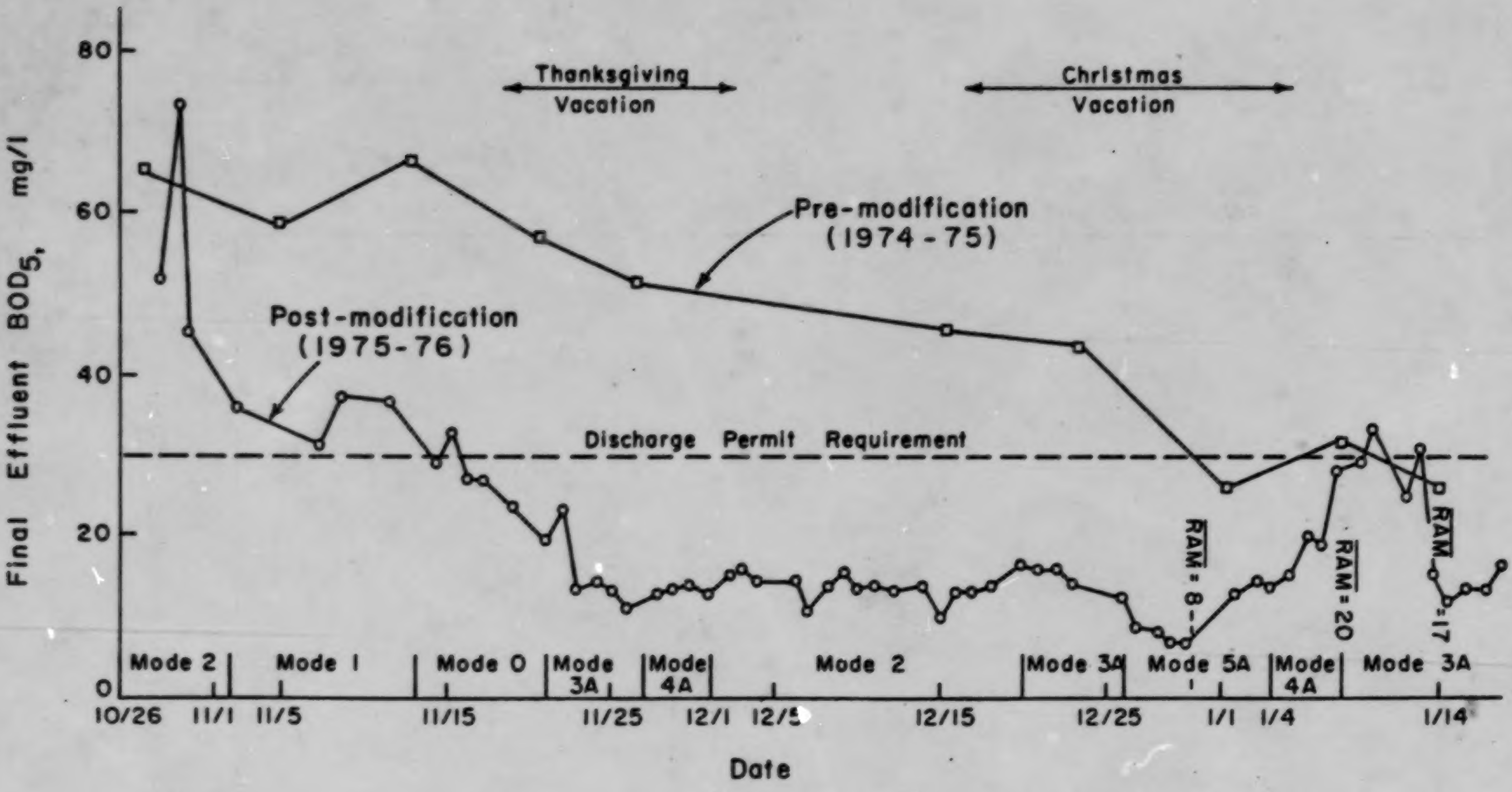


Fig. 7 Improvement In Activated Sludge Process Performance as a Result of Biomas Respiration Rate Control, Pullman Wastewater Treatment Plant

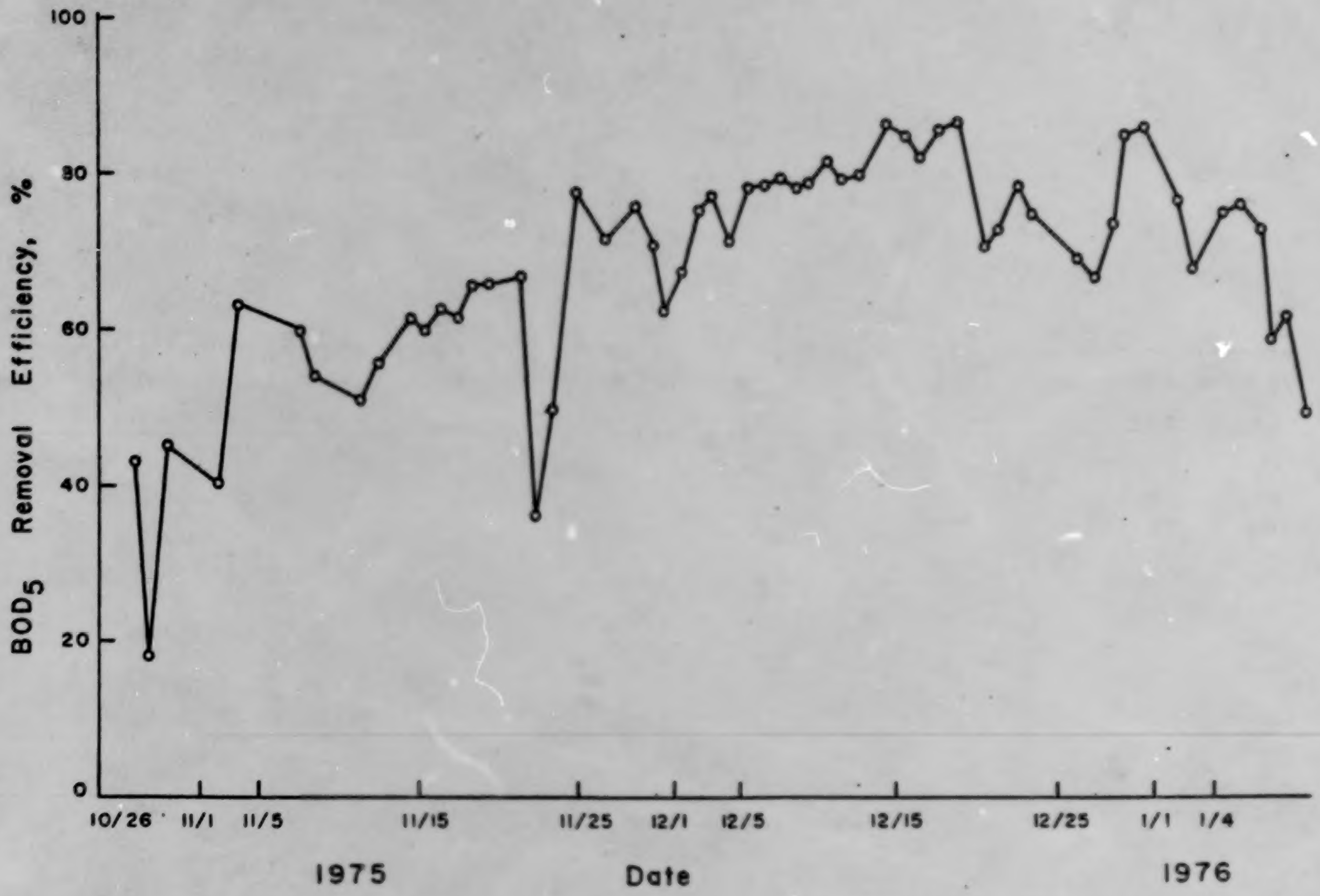


Fig. 8 BOD Removal Efficiency in the Activated Sludge Process (Based on Primary Effluent to Final Effluent)

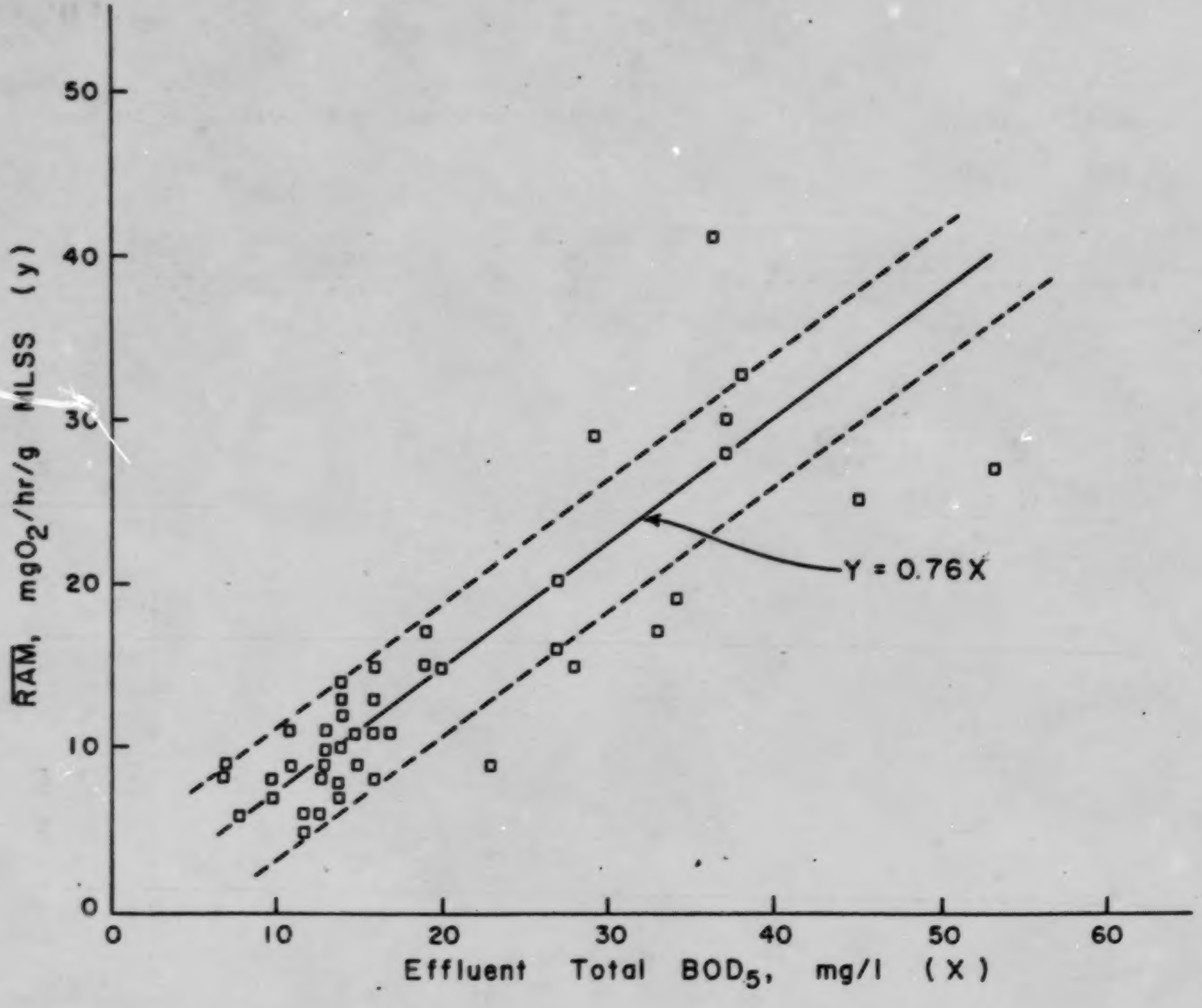


Fig. 9 Relationship between $\overline{RAM}$ value and Effluent Total BOD_5 (Daily Average Values)

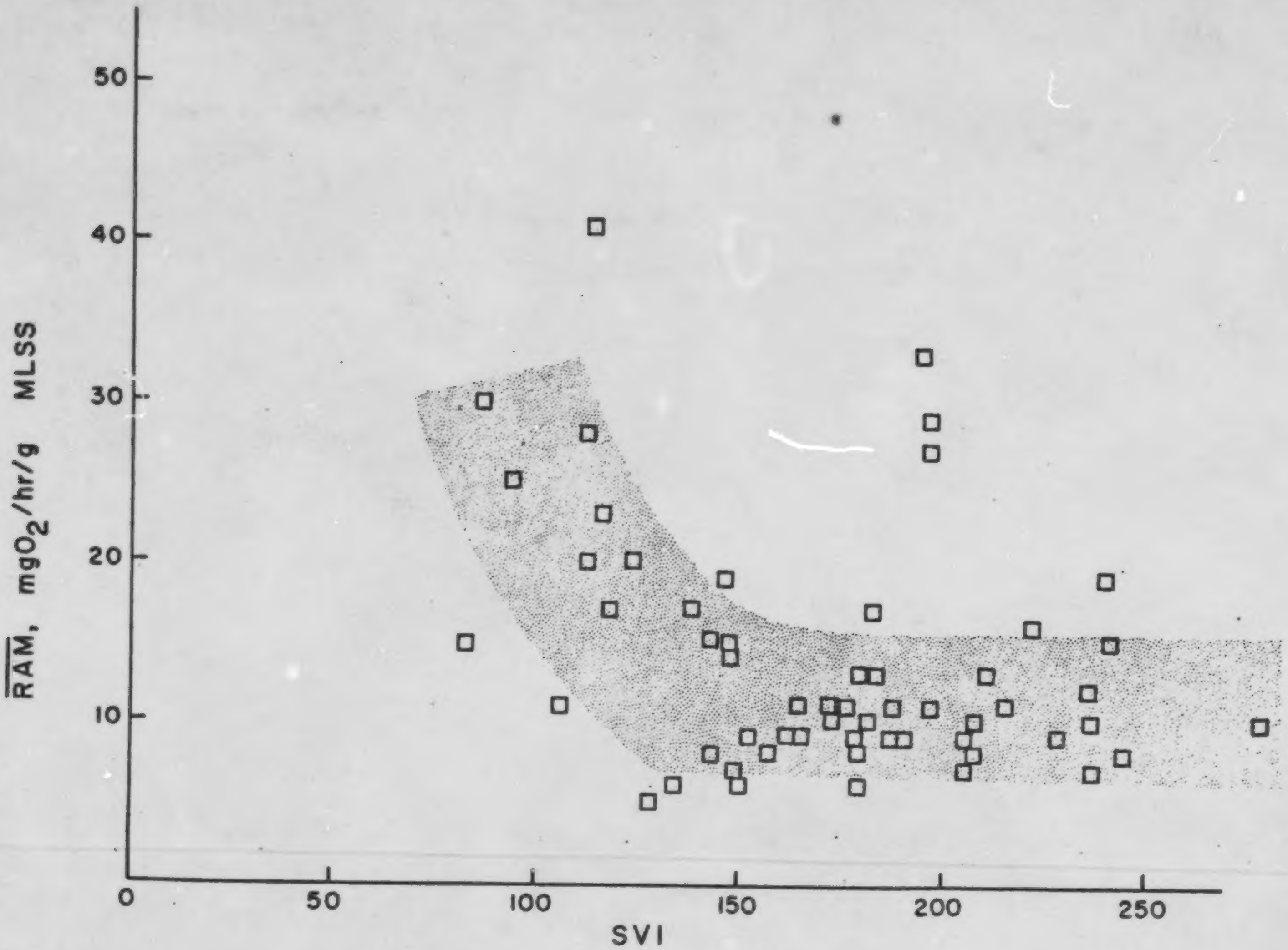


Fig. 10 Relationship between $\overline{RAM}$ and SVI (Daily Average Values)

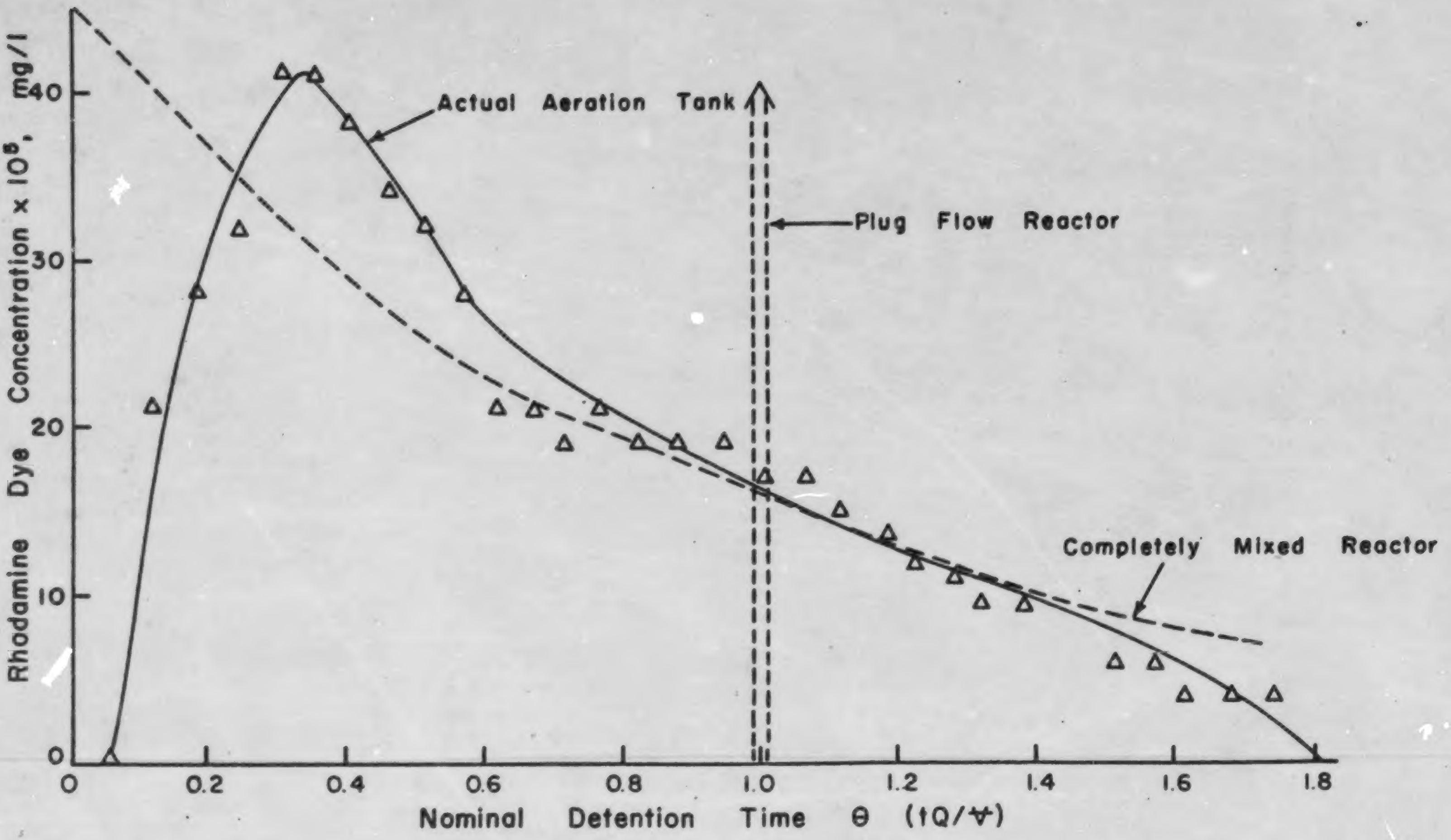


Fig. II Time Concentration Curve for the Aeration Tank (Rhodamine WT)

List of Tables

Table 1. Average Process Parameters for Each Mode of Operation (1975-76).

TABLE 1. Average Process Parameters for Each Mode of Operation (1975-76).

Dates	Q mgd	$\overline{\text{RAW}}$, mgO_2/hr/gMLSS	BOD5,mg/ℓ Total Influent	BOD5, mg/ℓ Total Effluent	SS, mg/ℓ Total Effluent	% Removal Primary to Final	Theoretical* % Removal, Raw to Final	Mode
10/28-11/13	3.59	32	74	43	73	42	59	2 and 1
11/13-11/21	3.65	19	72	26	..	64	75	0
11/21-11/27	2.78	9	44	15	64†	66	76	3A
11/27-12/1	2.93	6	42	13	..	69	78	4A
12/1-12/20	4.74	10	70	14	26	80	86	2
12/20-12/26	2.82	9	57	15	..	74	82	3A
12/26-1/4	3.20	9	44	11	19†	75	83	5A
1/4-1/8	4.47	17	72	21	45†	71	80	4A
1/8-1/18	5.80	15	56	20	31†	64	75	3A

*Assuming an average of 30% BOD$_5$ removal by the primary clarifer.

†Single value.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 9: Pullman Treatment Plant

Trainee Notebook Contents

The Pullman Treatment Plant - Situation and Data T11.9.1

Simplified Flow Schematic - Pullman Treatment Plant T11.9.4

Pullman, Washington - Facts About the Plant . . . T11.9.5

Pullman Treatment Plant - Typical Influent Flow Pattern T11.9.6

Pullman Treatment Plant Performance T11.9.7

Pullman Troubleshooting Problem - Answer Sheet . . T11.9.8

1100

The Pullman Treatment Plant
Situation and Data

City of Pullman, Sewage Treatment Plant
Department of Public Works

This City of Pullman facility is operated by the Department of Public Works and treats the sewage from both the community and the Washington State University Campus. WSU contributes financially to the maintenance and operation of the plant.

The original plant was completed in 1949 at a cost of approximately $300,000. This plant was a bio-filtration type treatment plant.

Due to the increased use of water by the population, it became necessary to increase the capacity of the plant. To accomplish this, the plant was remodeled in 1965. At that time it was changed to an activated sludge type plant to more effectively treat both the low quantity of sewage received during the summer months and the high quantities received during the winter months with the return of the students to WSU. The remodeling cost was approximately $500,000.

Operational History

1. Plant is at maximum hydraulic capacity during wet weather. Flow in excess of 6.5 MGD is by-passed.
2. Student population from WSU affects plant loading. There is an infiltration/inflow problem.
3. It is hard to stabilize the plant operation during and after student vacations, particularly Thanksgiving and Christmas.
4. The plant has a weak sewage averaging between 80 and 120 mg/l BOD.
5. Historically, the plant has carried a low MLSS (about 1000 mg/l).
6. Aeration tanks have three sparge-turbine type aerators in each tank. Flow through the aeration basins approaches plug flow conditions.

7. The aeration basin has a hydrogen sulfide odor when the DO drops near 0.

8. No digester supernatant is returned to the system, all of it is hauled and disposed of on land.

9. Waste sludge is typically wasted back to the primary clarifiers.

10. The two aeration tanks are normally operated in parallel. The tanks cannot be operated in series. The plant can be operated using only one aeration tank.

The Problem

The typical influent flow pattern to the Pullman plant is presented as page T11.9.6. During periods of high flow solids washout occurs in the final clarifiers. Organic and hydraulic load to the plant increase during periods of peak campus activity, such as a home football game. During weekends, vacation periods and other major off-campus events, hydraulic and organic load to the plant drop abruptly and by large amounts. Infiltration and inflow add to hydraulic load problems at the plant.

The combination of hydraulic and organic load fluctuations and the weak sewage normally received at the plant create recurrent operational problems. The plant has historically produced a slow settling sludge (SVI > 200) which has made it difficult to build and maintain an adequate solids inventory. Consequently, the plant has great difficulty in producing a good effluent.

The Department of Public Works requested technical assistance in 1975 to analyze the operational problems at the plant and recommended alternate operating procedures and/or facility modifications which will make the plant operable. Limited funds (approximately $5000) were available for minor facility modifications and plant personnel provided labor at no cost to the project to fabricate or affect any modifications to the facility.

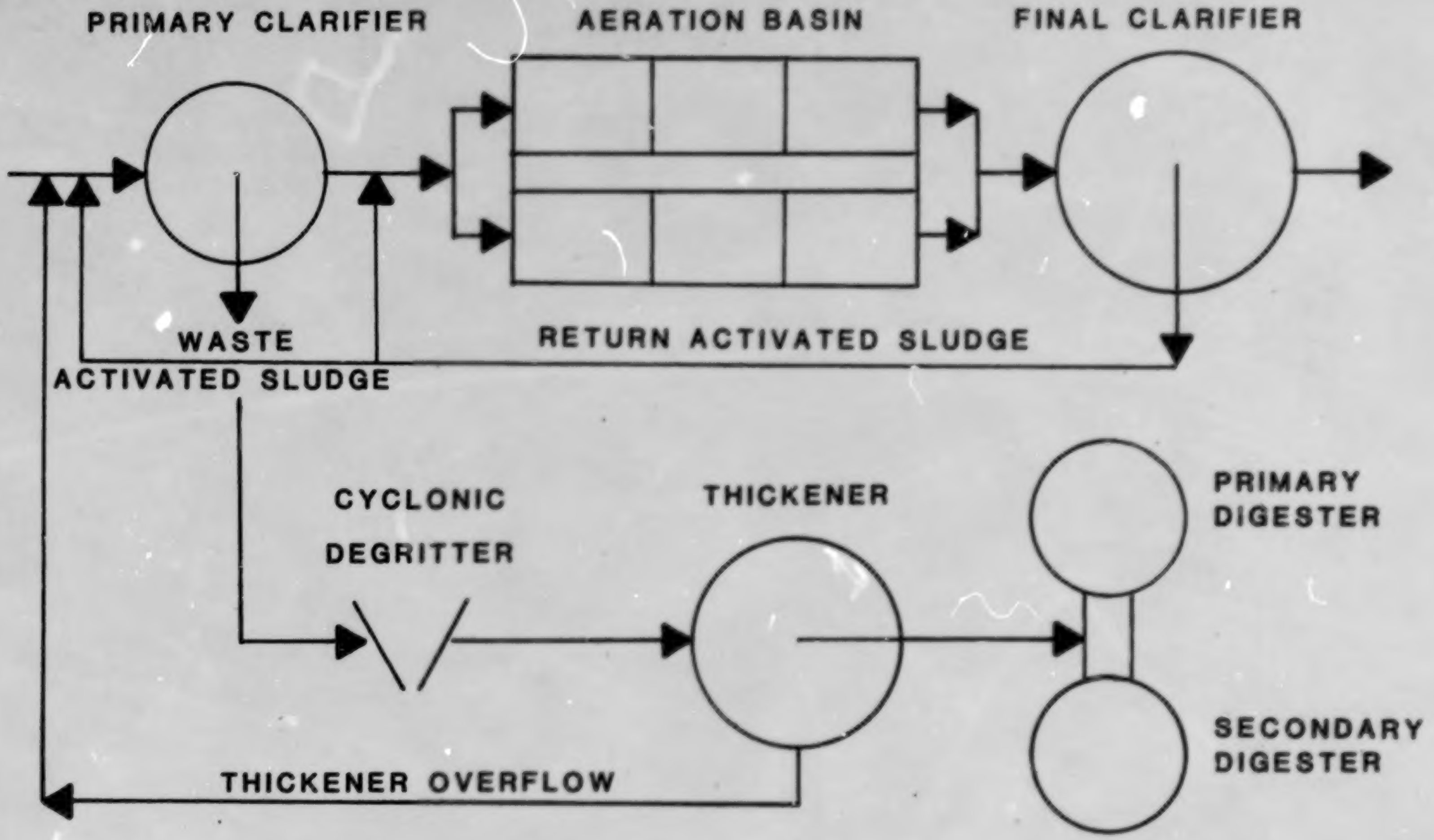
Needless-to-say, the troubleshooter's efforts and those of plant personnel were very successful. Page T11.9.7 presents effluent BOD data for November, 1974 and November, 1975. Note that by late November, 1975, effluent BOD had been reduced to about 20 mg/l. The plant continues to perform well.

Your task is to analyze the problems at the Pullman plant and make recommendations for operational procedures and/or minor facility modifications to achieve the results shown on page T11.9.7. Your task includes the definition of process control procedures which can be used to achieve and maintain the effluent quality results shown as page T11.9.7.

A simplified schematic flow diagram and design data for the Pullman Treatment Plant are presented as pages T11.9.4 and T11.9.5 respectively.

You, working with your work group, are to analyze the Pullman plant and develop specific recommendations to improve the plant's performance. Use the answer sheet on page T11.9.8 as a guide in developing your recommendations. In the next lesson you will report your findings to the class.

T11.9.4



SIMPLIFIED FLOW SCHEMATIC - PULLMAN TREATMENT PLANT

Pullman, Washington - Facts About the Plant

Design Flow:

Minimum Daily Flow	2.80 Million Gallons per Day
Average Daily Flow	4.00 Million Gallons per Day
Maximum Daily Flow	6.50 Million Gallons per Day
Maximum Hydraulic Flow	12.00 Million Gallons per Day

Strength of Sewage:

	Suspended Solids	BOD
Minimum	140 ppm	120 ppm
Average	225 ppm	210 ppm
Maximum	270 ppm	250 ppm

Pump Station:

Five Raw Sewage Pumps
- 2 rated 1,000 gpm @ 13' of head each
- 3 rated 2,100 gpm @ 13' of head each

Volume, wet pit at overflow: 8,950 gallons

Primary Clarifier:

Diameter: 70'
Side wall depth: 8.5' Volume: 246,000 gallons

Aeration Basins:

Two Basins: Volume of each: 350,000 gallons
Blower Capacity: 3 blowers, each @ 600 cfm
Activated Sludge Pumps: 2 pumps, each @ 1,600 gpm @ 35' of head

Secondary Clarifier:

Diameter: 70'
Side wall depth: 11'

Chlorine Retention Basin:

1 Basin Retention Time: 20 min. minimum

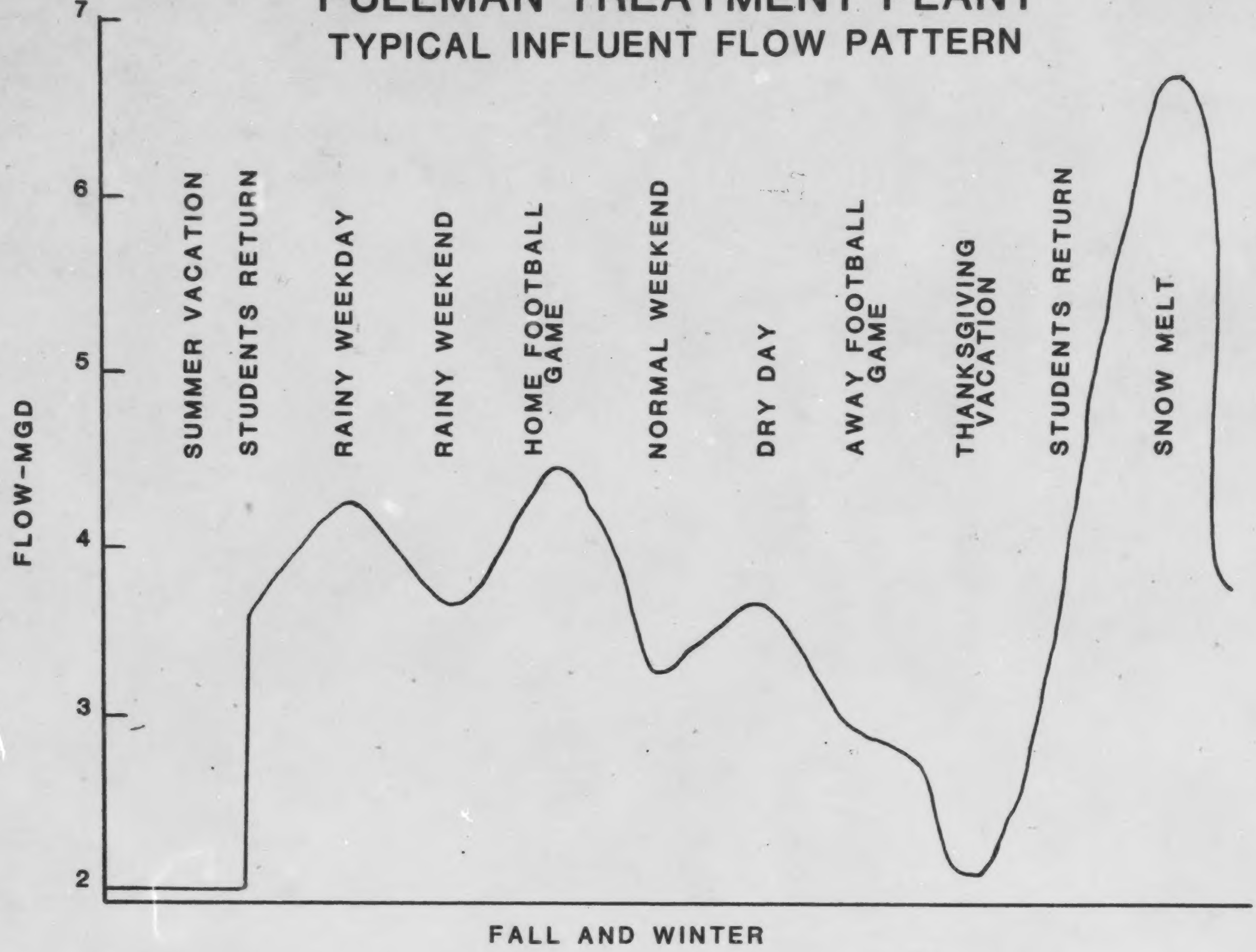
Sludge Thickener:

Diameter: 30'
Side wall depth: 10' Volume: 53,000 gallons

Sludge Digesters:

Primary:	Diameter:	35'	Volume:	176,200 gallons
	Side wall depth:	23'		
Secondary:	Diameter	35'	Volume:	161,200 gallons
	Side wall depth:	21'		
			Total Volume:	337,400 gallons

PULLMAN TREATMENT PLANT
TYPICAL INFLUENT FLOW PATTERN



T11.9.6

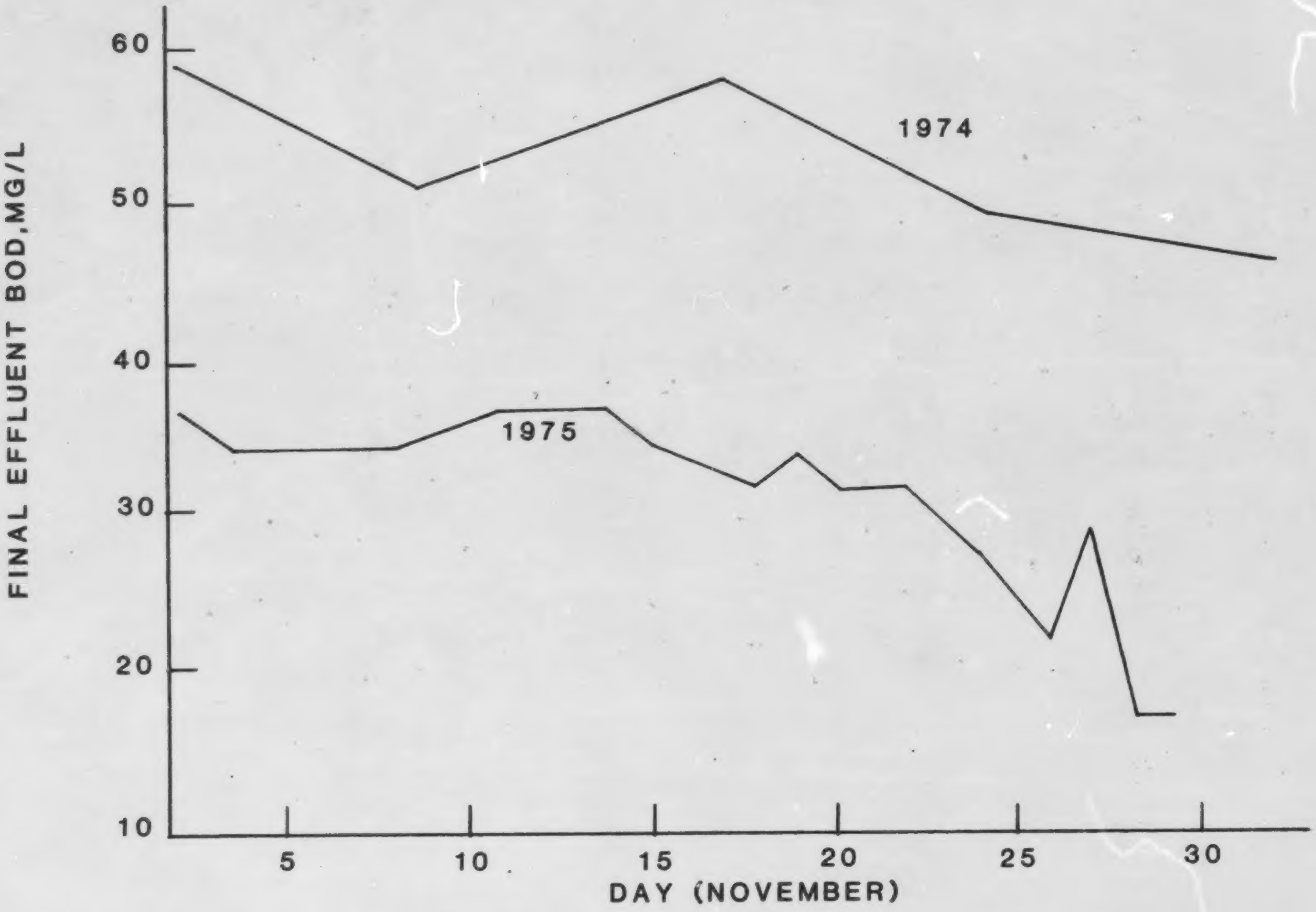
1107

1108

PULLMAN TREATMENT PLANT PERFORMANCE

BEFORE (1974) AND AFTER (1975) TECHNICAL ASSISTANCE PROJECT

T11.9.7



Activated Sludge Process Troubleshooting

Pullman Troubleshooting Problem - Answer Sheet

STUDENT GROUP # ______

1. Briefly describe and define the problem that existed at Pullman in 1974.

2. Using the *Process of Troubleshooting*, describe:

   a. The data you would need

   b. The analysis you would make

3. What process changes would you recommend to cope with the fluctuating load? What other changes?

4. What process control strategy would you use to control the activated sludge process? How would you do it?

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 10: Case History: Pullman Treatment Plant - Solution

Lesson 10 of 14 lessons   Recommended Time: 50 minutes

Purpose: Report and discuss trainee responses to the problem presented as Unit 11, Lesson 9. The solution actually implemented at the Pullman Treatment Plant is presented and discussed to illustrate how process mode change can be achieved by modifying the activated sludge return system at a treatment plant and how respiration rate measurements can be used to anticipate influent load changes, monitor process condition and adjust plant operations to achieve consistent effluent quality.

Trainee Entry Level Behavior: Trainees will have achieved the learning objectives specified for Unit 11, Lessons 1 - 9 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. Demonstrate understanding of the process of troubleshooting by reporting how the process was used to solve a case history problem and presenting recommendations for solution to the problem.

2. Explain how respiration rate, sludge settleability and a step feed process can be used to respond to erratic influent and extreme organic and hydraulic loadings and explain how the concept can be applied to other situations.

Instructional Approach: Trainee discussion

Lesson Schedule: The 50 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 30 minutes	Trainee Reports of Findings
30 - 50 minutes	Solution Implemented at Pullman

Trainee Materials Used in Lesson: As specified in Unit 11, Lesson 9.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 11, Lesson 10, pages 11.10.1 - 11.10.6
2. *Instructor Notebook*, page H11.10.1 - H11.10.11, "Case History - Pullman Treatment Plant - Solution Implemented." (Reproduce these pages for distribution to class during lesson.)
3. Slides 179.2/11.10.1 - 179.2/11.10.8.

Instructor Materials Recommended for Development: None

Additional Instructor References: As specified in Unit 11, Lesson 9.

Classroom Set-Up: As specified in Unit 11, Lesson 1.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Trainee Reports of Findings (30 minutes)	Problem statement is included in the *Trainee Notebook* as pages T11.9.1 - T11.9.8.
A. Call on work groups in turn to report findings and recommendations for the Pullman Problem.	Use Slide 179.2/11.10.1 Slide 179.2/11.10.1 is a blank
B. Encourage discussion of trainee findings. Encourage trainee critique of findings in context of the limitations imposed by the problem, i.e., $5000 limit on expenditure for modification.	The $5000 limit on modifications precludes conversion to provide step feed capability in the traditional way. The solution actually implemented provides a "step sludge" capability which accomplishes the same objective.
C. Trainees frequently recommend that an opening be made in the common wall between the aeration basins to provide for sludge reaeration modes of operation. This solution should be discouraged because: 1. Structural damage to aeration basin walls. 2. Permanentness of this solution, i.e., if it doesn't work, you may have created a new set of problems by irreversible damage to the aeration basin. (Troubleshooting Rule of Thumb: Don't do anything that you can't reverse later). 3. Probably can't do this with the limited dollars available.	From a process point of view this is a good solution. It provides for sludge reaeration and control of sludge aeration time and solids inventory. The solution actually implemented does the same thing but in a novel way by providing a capability to step feed return sludge. Pullman also tried various systems to balance and supplement load to the plant by using digester supernate as a feed source, by-passing the primary tanks and using the sludge thickener as a sludge storage container.
II. Solution Implemented at Pullman (20 minutes)	Distribute pages H11.10.1 - H11.10.11 to the class.
A. Installation of modified return activated sludge	
1. Note flow diagram, Trainee Handout page H11.10.6.	Use Slide 179.2/11.10.2 Slide 179.2/11.10.2 is a reproduction of page H11.10.6.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Describe how the system was installed This was accomplished by attaching a 6-inch irrigation line onto the existing return sludge pipeline and extending it down the center of the two aeration tanks with valves installed on inlet points at three places into each aeration tank. Return sludge could then be introduced into the aeration tank at variable points in order to change the sludge characteristics.	
B. Aerator Mode System	
1. Note diagram of aerator modes, Trainee Handout page H11.10.7.	Use Slide 179.2/11.10.3 Slide 179.2/11.10.3 is a reproduction of page H11.10.7.
2. Describe the mode system. Designations were set up for the various modes of operation for transmitting information to operators on different shifts. Mode 0 was designated as the one where return sludge was fed at the head end of each aeration tank. (Normal operational mode prior to modification of the return sludge system.) Mode No. 1 would be a situation where return sludge was fed to the second portion of one side and the head end of the other tank. Shaded areas designate the amount of the relative tank volume that was receiving return sludge and primary effluent. Unshaded portions are primary effluent only.	
C. Sampling for Process Control	
1. Note diagram, Trainee Handout page H11.10.8.	Use Slide 179.2/11.10.4 Slide 179.2/11.10.4 is a reproduction of page H11.10.8.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Describe the sampling scheme	
Samples were taken at the designated points shown with the major control point being that of No. 4, the mixed liquor respiration rate at the outlet of the aeration tank, and No. 9, the respiration rate of a mixture of return sludge and primary effluent, the fed sludge RR sample.	
3. Relationship between MLSS RR and effluent quality was noted.	
a. Refer to Trainee Handout page H11.10.9 to show improvement in effluent quality as MLSS RR decreased.	Use Slide 179.2/11.10.5 Slide 179.2/11.10.5 is a reproduction of page H11.10.9.
b. Optimum range for MLSS RR was determined to be 8 - 20 mg O_2/hr/gm as shown in Trainee Handout page H11.10.11 which shows both effluent BOD and MLSS RR as a function of time.	Use Slide 179.2/11.10.6 Slide 179.2/11.10.6 is a reproduction of page H11.10.11.
c. MLSS RR in range 8-20 mg O_2/hr/gm coincided with slude stability which gave best settling.	
D. Control Strategy - Respiration Rate	
1. Sludge Aeration Time Control	Use Slide 179.2/11.10.6 to illustrate this point
a. Eight to twenty milligrams O_2/gram MLSS/hour is the optimum range for MLSS RR.	
b. If the MLSS RR trend is toward a higher respiration rate, move return sludge point toward head end of plant and increase sludge aeration time. If trend is downward, then move to shorter sludge aeration time.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2. Return Sludge Control a. Procedure Used. A constant was determined for the combination of respiration rate of the primary effluent mixed with return sludge divided by return sludge rate. The F/M control optimum range was found by trial and error. Operators took a reading approximately three times a day and adjusted the return rate to maintain this constant.	
b. F/M based on fed sludge RR $K = \frac{\text{Fed Sludge RR} \times Q}{\text{Conc. RAS} \times Q_R}$ Where Q_R = Return Sludge Rate Therefore, by finding the optimum constant, the operator can then adjust the return rate to continue good performance. $QR = \frac{\text{Fed Sludge RR} \times Q}{\text{Conc. RAS} \times K}$	Write equation on chalkboard. Note that this is an F/M type formulation with food measured by Fed Sludge RR and Mass approximated by the rate at which sludge solids are recycled to the process. Strategy based on constant F/M control.
F. Results Achieved	
1. Consistently low effluent BOD Refer class to Trainee Handout page H11.10.6.	Use Slide 179.2/11.10.6 to illustrate consistent control achieved.
2. Able to respond to wide variations in influent organic and hydraulic loads Refer class to Trainee Handout page H11.10.10.	Use Slide 179.2/11.10.7 Slide 179.2/11.10.7 is a reproduction of page H11.10.10.
G. Credit problem to Danny Johnson, City of Pullman, Washington and his co-workers. Mr. C. Zickefoose should be credited with the basic idea which was implemented by others.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
III. Discussion	Use Slide 179.2/11.10.8 Slide 179.2/11.10.8 is a blank
A. Use any remaining time for discussion of the process control concepts used in this lesson.	
B. Point out basic principles used to control sludge stability as measured by MLSS RR and looking for ways to vary and control the process variables which have most impact on sludge stability: 1. Sludge aeration time 2. Solids inventory 3. Organic loading	
C. Use problem to illustrate the innovative way in which the Pullman operators with some outside assistance were able to recognize the root cause of their problem and then devise a way to respond to and control the cause of the problem: 1. Variable sludge aeration time 2. Variable or inadequate solids inventory 3. Variable organic loading	

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 10: Pullman Treatment Plant - Solution

Instructor Handout Contents

Pullman Wastewater Treatment Facility -
Solution Implemented . . . . H11.10.1 - H11.10.5

Activated Sludge Process Troubleshooting

Pullman Wastewater Treatment Facility

Solution Implemented

The Problem

The problem at Pullman was multi-fold:

1. Variable and uncontrollable aeration basin detention time,
2. Variable and uncontrollable solids aeration time,
3. Variable organic load to the facility,
4. Hydraulic wash-out of solids from the final clarifier, and
5. Limited process flexibility to respond to changes in load or process conditions.

The problems at Pullman were caused by:

1. Variable and high influent flow rates,
2. Variable and low influent organic load, and
3. Lack of process flexibility to respond to changing load and process conditions.

This combination of problems and causes prevented the system from developing and maintaining an adequate solids inventory. Because of inadequate solids inventory and short variable aeration basin and solids aeration detention times the process operated with a thin, slow settling, understabilized sludge which could not adequately treat the applied load and which could not be separated and concentrated in the final clarifier.

Tests to Confirm the Problems and Their Causes

Sampling and analysis of the following process streams and data should be performed to identify the problems and their causes:

Influent:	Flow Rate Applied BOD Fed Sludge RR
Mixed Liquor:	Aeration Detention Time Solids Aeration Time Solids Inventory MLSS Concentration MLSS RR MLSS Settleability
Return Sludge:	Flow Rate RAS Concentration Unfed Sludge RR
Final Clarifier:	Clarifier Loadings Sludge Blanket Depth Variations in Blanket Depth with Applied Load
Final Effluent:	Effluent BOD Effluent Suspended Solids

Alternative Solutions

1. Variable Load: Use flow and load equalization. Rejected because funds not available to implement.

2. Augment and Balance Organic Load: By-pass primary clarifier or feed digester supernate to augment and balance the applied load. Tried without success.

3. Use Thickener Solids to Supplement Aeration Basin Solids and Operate Thickener as a "Sludge Reservior." Tried without success.

4. Convert Plant to Step Feed: Provide capability to distribute load along length of aeration basins. Rejected because funds not available to implement this major design and construction modification.

5. Provide Capability to Operate as Contact Stabilization or Sludge Reaeration Plant: Convert one aeration basin to sludge reaeration by opening a channel between the two aerator basins and repiping the return sludge to feed one basin as sludge reaeration tank. Rejected because of potential structural damage to the common aeration basin wall, because aeration tanks would be out of service while modification was made, and because cost exceeded available funds.

6. Repipe Return Sludge to Convert Process to a "Step Sludge" Process: Implemented. (Note: The consultant, Mr. Charles S. Zickefoose of STRAAM Engineers, Inc., Portland, Oregon, had previous experience with a similar problem and approach at Hillsboro, Oregon, before this project began.)

The Modified Plant

Alterations

The alteration was accomplished by connecting a 6" irrigation pipe to the existing return sludge line and running the 6" line down the center of the common wall separating the two aeration basins. The line was fitted with three tees and six valves to provide capability to release return sludge at six points in the aeration basin. A schematic of the modification is shown as page H11.10.6.

Operating Modes

Because the aeration basin had the characteristics of plug flow, this return arrangement permitted multi-mode operations as shown on page H11.10.7 Each mode was numbered, as shown, as a communication aid to operating personnel. Primary effluent always entered at the head of the aeration basin. The point of return sludge discharge was varied to respond to loading and process demands.

Modes 0 - 4 use both aeration basins. Mode 0 represents the typical system operation before the modification was constructed. Mode 0 creates high oxidation pressure (long sludge aeration time) and is used when flow rates are moderate and influent organic load is high. Successive steps through Modes 1 - 5 reduce the oxidation pressures in the system and are used as the organic load decreases at moderate flows.

When both flow and organic load are low, modes 3A - 5A are used with one side of the aeration basin serving as a "sludge holding reservoir." The sludge in the "holding reservoir" is aerated but not continuously fed (i.e., no primary effluent enters this side of the tank). The stored sludge is periodically fed by introducing primary effluent for about one hour per day. The other side of the tank receives both return sludge and primary effluent with oxidation pressure decreasing as the return point is moved from mode 3A to Mode 5A. The "sludge reservoir" side of the basin is put back into service as organic load increases and process demands dictate.

Modes 3A - 5A are also used when the plant approaches or exceeds the 4.0 MGD average daily design flow. High flows are partially treated while half the aeration tank is used to store sludge and prevent hydraulic wash-out of a major portion of the sludge solids.

Normal operation of the plant is between Modes 1, 2 and 3.

Process Control for Mode Change

The operating mode used is determined by monitoring and responding to changes in the MLSS RR and sludge settleability. The operators found that the best effluent quality was obtained when the MLSS RR was kept in the range 8 - 20 mg O_2/hr/gm. The MLSS RR is monitored once each operating shift (three times per day). If the MLSS RR increases and exceeds 20 mg O_2/hr/gm the operator moves the return sludge discharge point to the next lower numbered operating mode to increase the oxidation pressure. If the MLSS RR decreases and drops to or below 8 mg O_2/hr/gm, the operator moves the return sludge discharge point to the next higher numbered operating mode to decrease the oxidation pressure.

Closer control could be achieved by defining a narrower band for the optimum MLSS RR range.

If the plant is operating in Mode 0 and the MLSS RR continues to increase, the operator then moves to Mode 3A to use half the aeration basin for sludge reaeration and storage. This change requires the approval of the operator's supervisor before it can be made.

Return Sludge Control

The plant uses a modified constant F/M strategy to determine return sludge flow rate changes. The modified F/M used for return sludge control is defined as:

$$K = \frac{\text{Fed Sludge RR} \times Q}{\text{RAS Conc.} \times Q_R}$$

where K = desired "constant F/M"

Fed Sludge RR = RR of a mixture of return activated sludge and primary effluent

Q = primary effluent flow rate, MGD

RAS Conc. = concentration of solids in the return activated sludge measured by centrifuge

Q_R = return activated sludge flow rate, MGD

Thus, the return sludge flow rate can be determined as:

$$Q_R = \frac{\text{Fed Sludge RR} \times Q}{\text{RAS Conc.} \times K}$$

"K" was determined empirically during a period when the plant was performing well. The "K" value is periodically redefined by supervisory personnel to account for changes in organic load.

The operators perform the laboratory analyses and adjust the return sludge flow rate three times per day (once per operating shift).

Waste Sludge Control

If the solids inventory in the system increases, the decreased F/M and increased sludge aeration time will cause the MLSS RR to decrease. This causes the operators to adjust the return sludge discharge point toward a higher numbered operating mode. When the system reaches Mode 3, supervisory personnel evaluate the system and direct increased wasting as appropriate. Conversely, when operation moves from Mode 2 to Mode 1, supervisory personnel review wasting policy and reduce wasting as appropriate.

Process Control Sampling

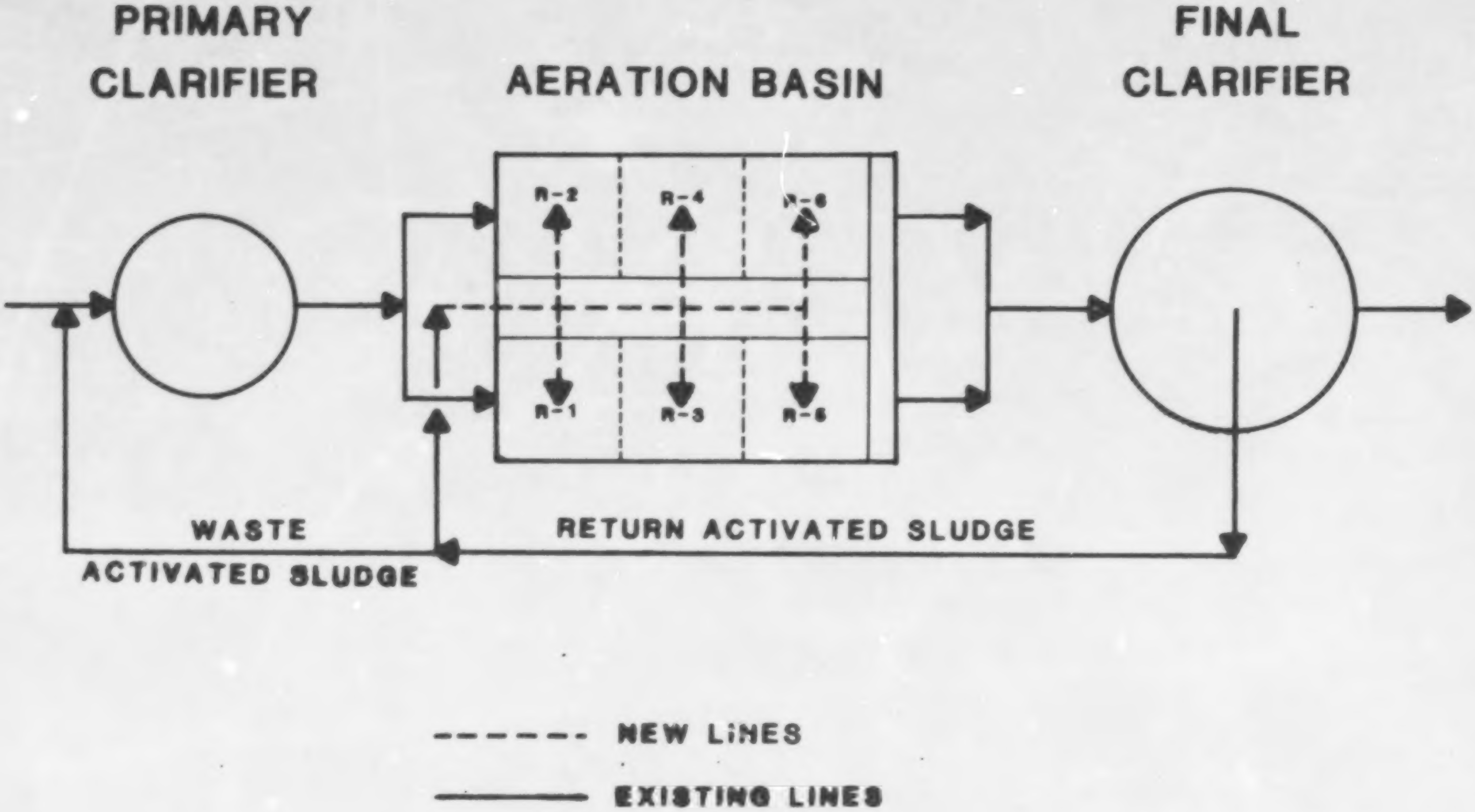
Page H11.10.8 identifies sampling locations, frequency and tests used for process control.

Although this test schedule is specific to the Pullman Treatment Plant, the schedule given would be appropriate for any plant operating with three shifts. The testing indicated gives a "good handle" on process condition.

Results Achieved

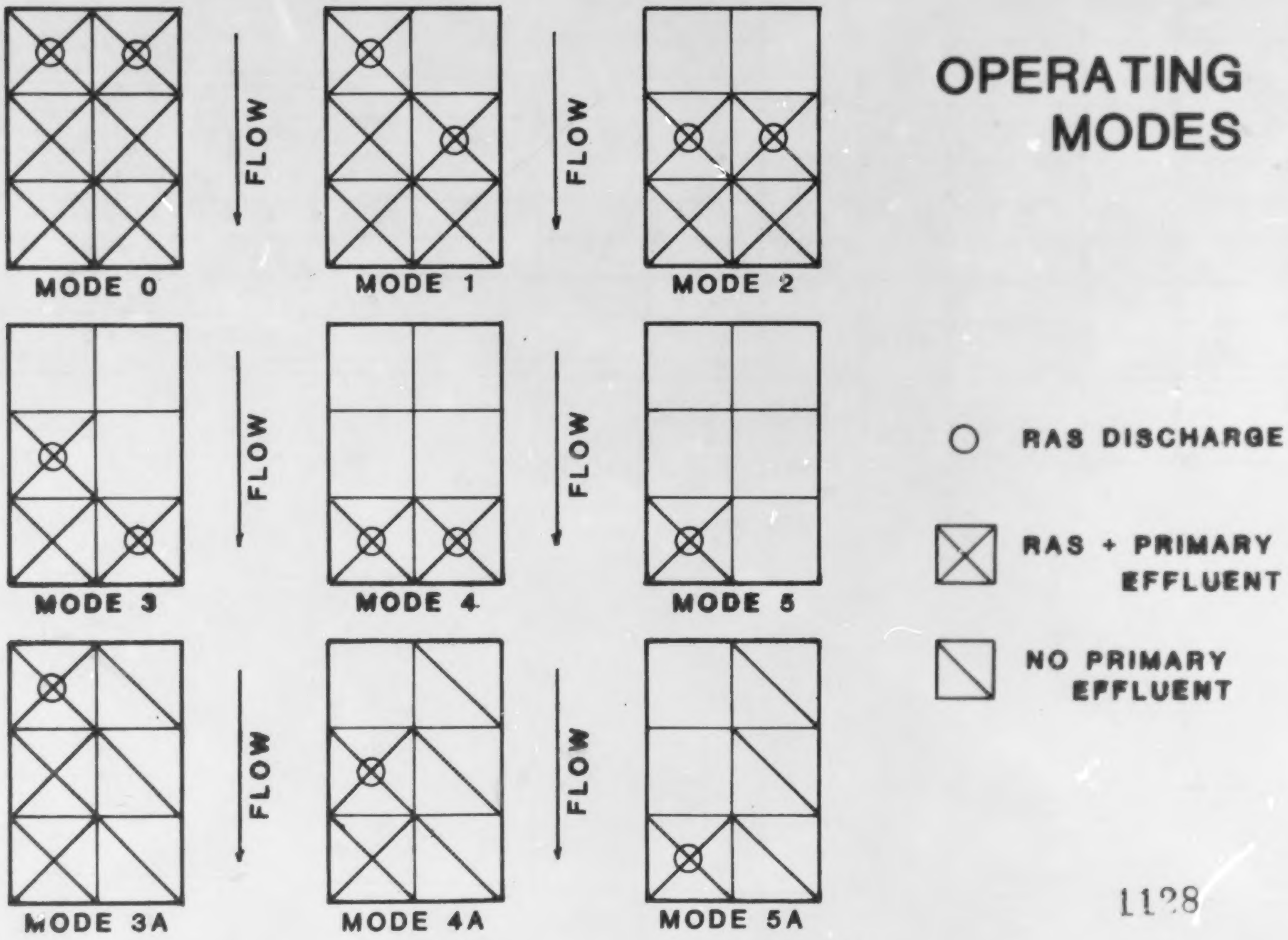
Pages H11.10.9-H11.10.11 summarize performance data for November and December, 1975. Note that the plant produces a consistently good effluent and is able to respond well to very wide variations in applied load, both hydraulic and organic.

H11.10.6

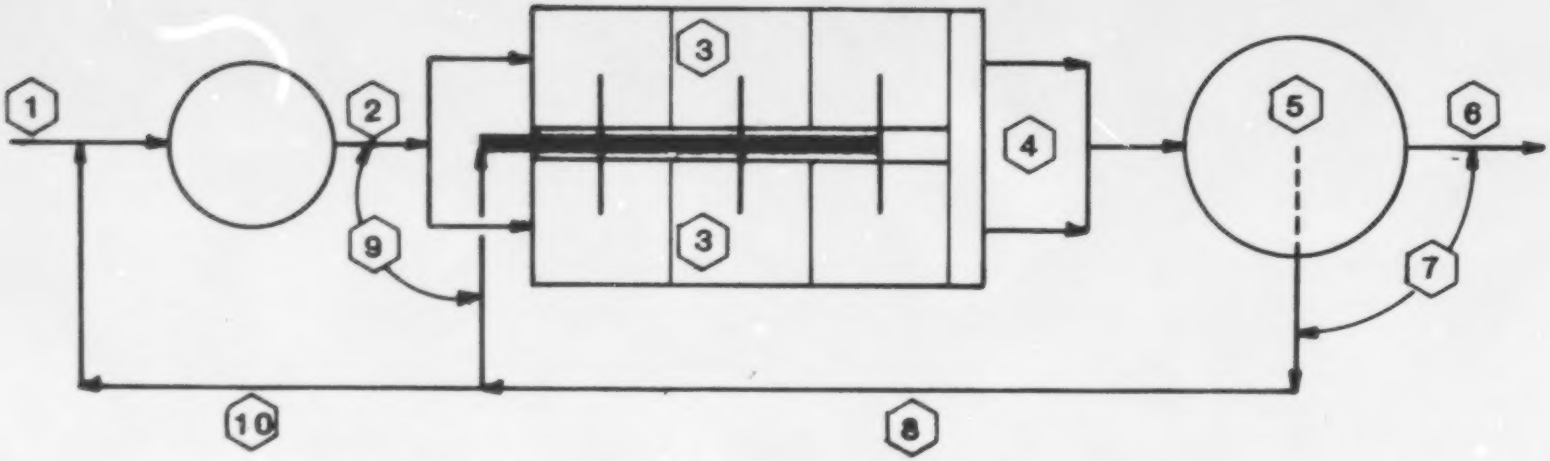


MODIFIED RETURN SLUDGE SYSTEM

OPERATING MODES



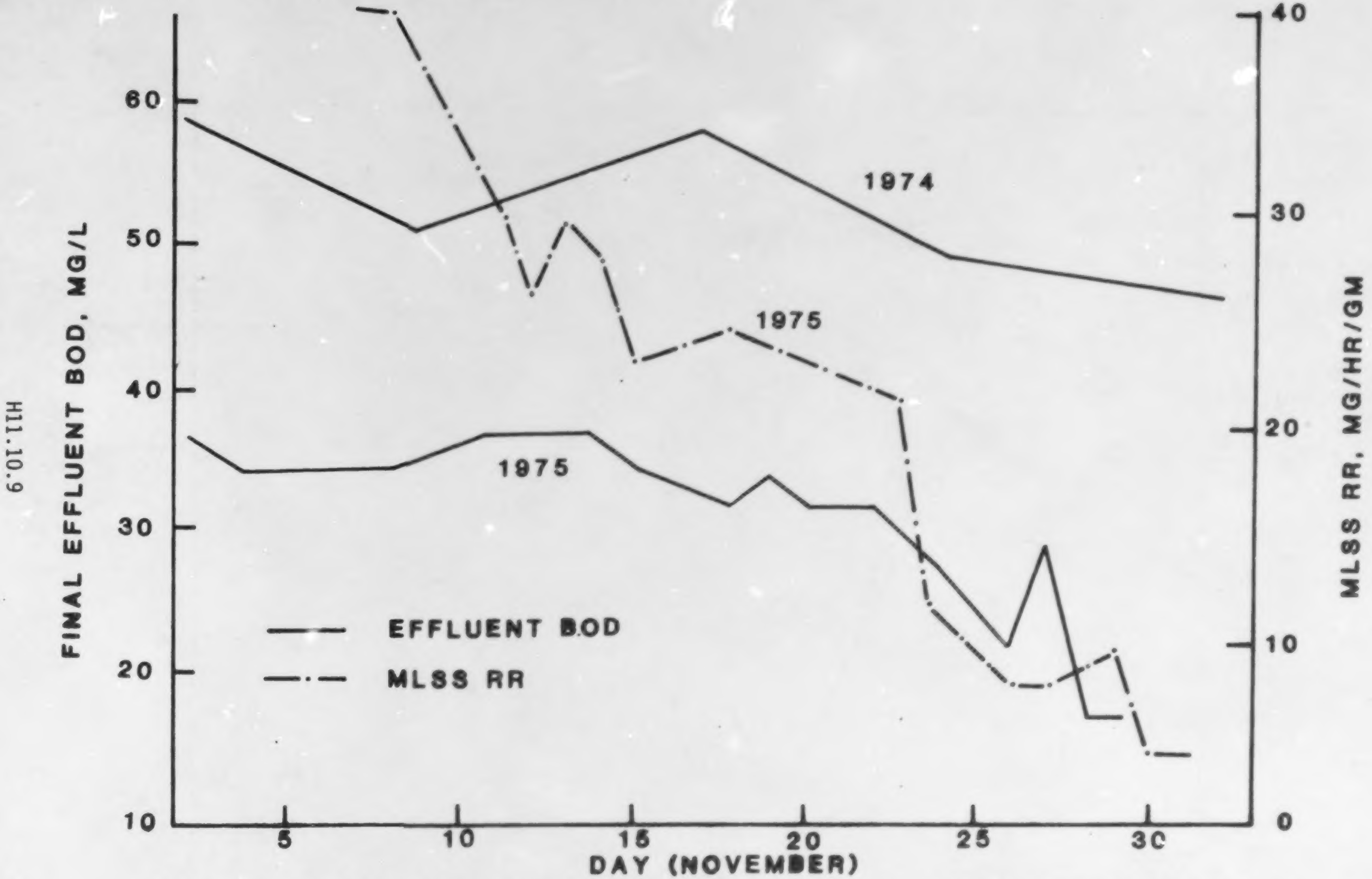
H11.10.8



SAMPLE POINTS AND FREQUENCY

SAMPLE	FLOW	SOLIDS		BOD	% SET.	RR	DOB
		GRAV.	CENT.				
1 RAW WASTE	C	4/W		4/W			
2 PRIMARY EFFLUENT	C	4/W		4/W			
3 MIXED LIQUOR			2/D				
4 AERATION BASIN EFFLUENT		1/D	4/D		3/D	3/D	
5 FINAL CLARIFIER							2/D
6 FINAL EFFLUENT		4/W		4/W			
7 UNFED SLUDGE			3/D			3/D	
8 RETURN SLUDGE	C	1/D	4/D				
9 FED SLUDGE			3/D			3/D	
10 WASTE SLUDGE	C	1/D	3/D				

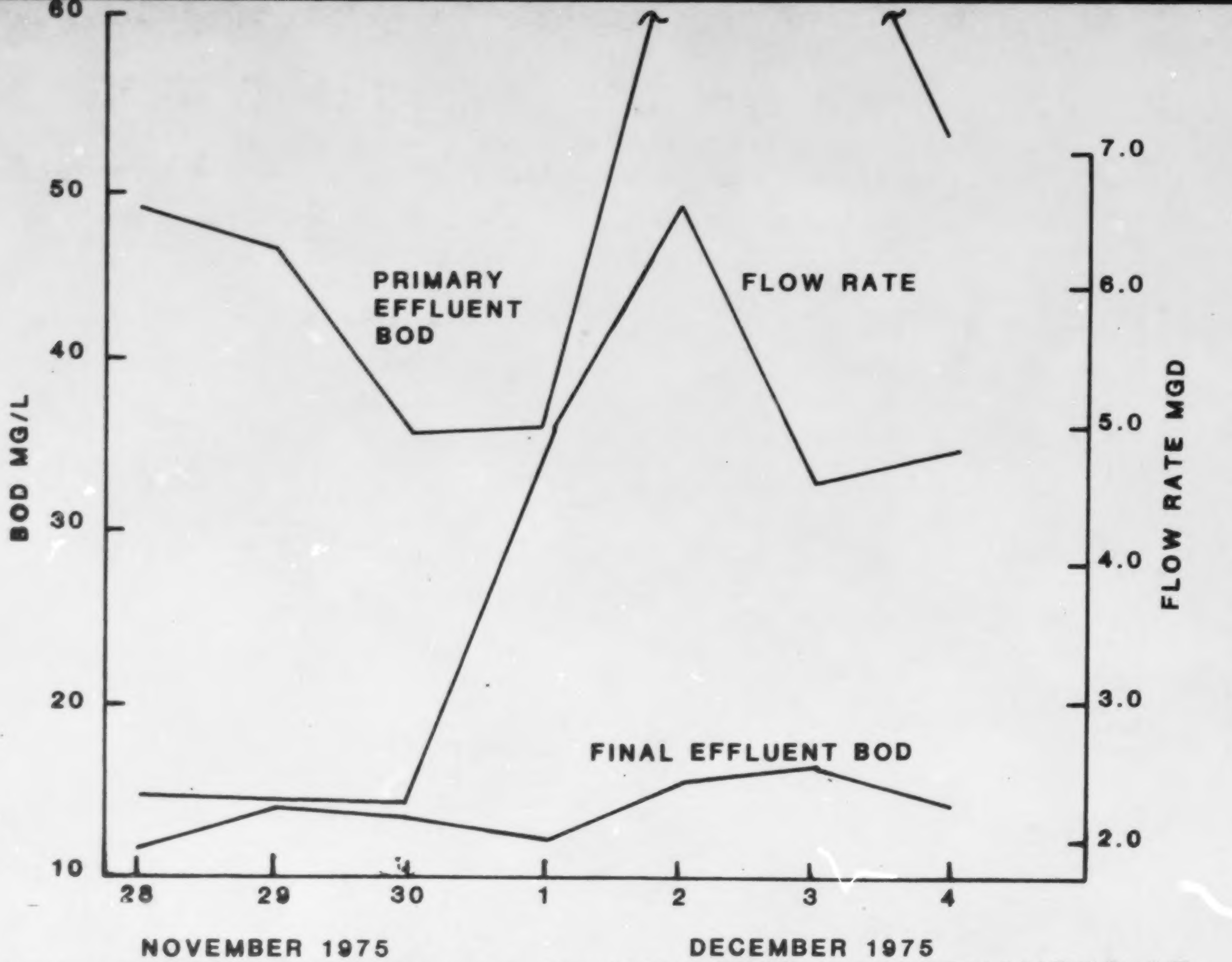
C - CONTINUOUS #/W - #/WEEK #/D - #/DAY



PULLMAN TREATMENT PLANT PERFORMANCE

1131

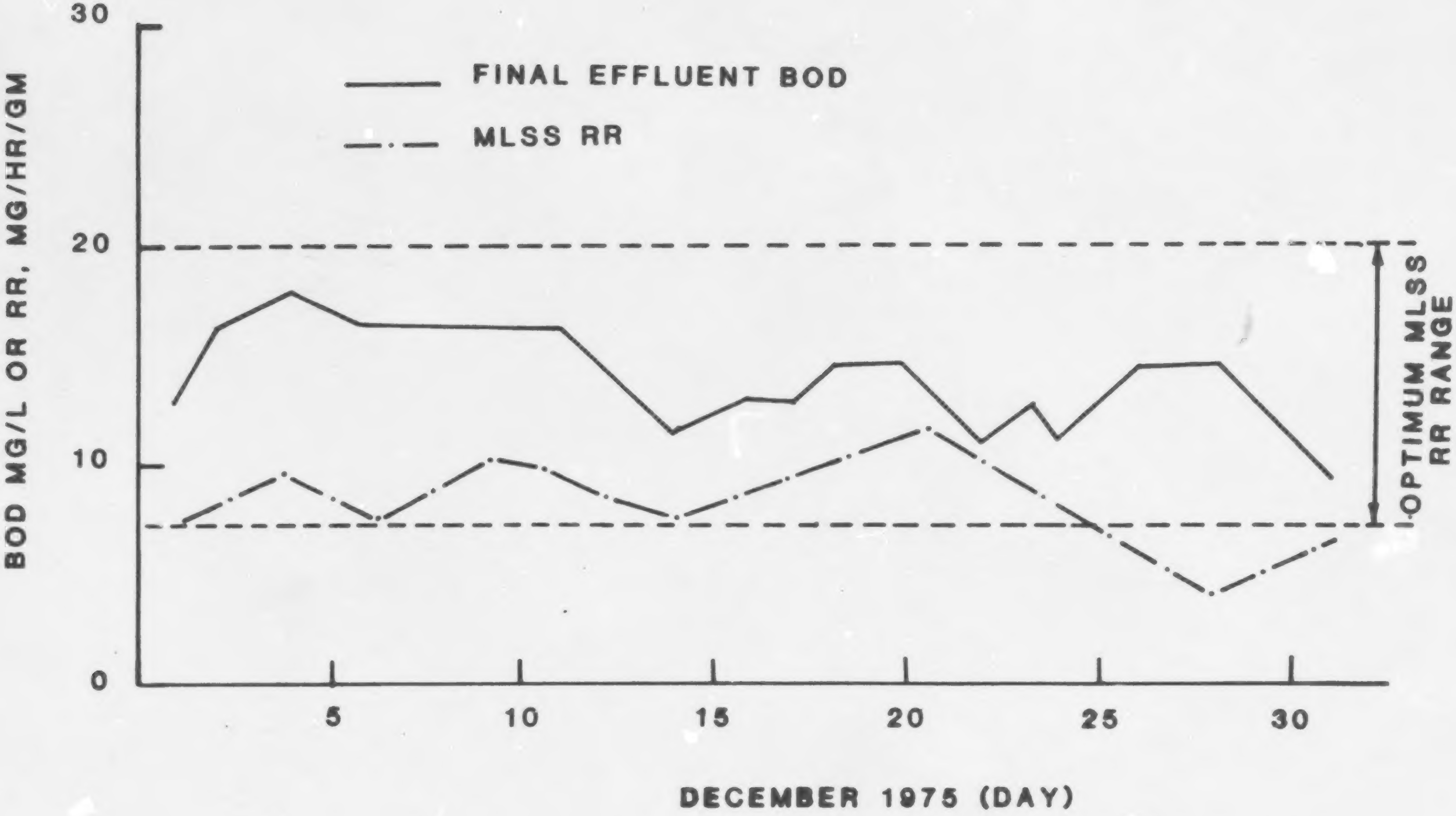
1132



H11.10.10

FINAL EFFLUENT RESPONSE TO INFLUENT LOAD CHANGES AT PULLMAN TREATMENT USING MODIFIED RETURN SLUDGE SYSTEM AND RR CONTROL

H11.10.11



PERFORMANCE OF PULLMAN TREATMENT PLANT USING MODIFIED RETURN SLUDGE SYSTEM AND RR CONTROL

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 11: Hamsborough Case History

Lesson 11 of 14 lessons Recommended Time: 60 minutes

Purpose: The case history problem solving exercise presented in this lesson permits the trainee to apply the *Process of Troubleshooting* to a small treatment plant which suffers multiple O & M problems in solids handling, activated sludge process operation and the process control laboratory. The problem illustrates the use of relatively inexpensive process modifications which were fabricated by plant personnel to improve the plant's operations.

Trainee Entry Level Behavior: The trainee should have achieved the learning objectives specified for Unit 11, Lessons 1 - 8 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. Demonstrate his/her ability to apply the *Process of Troubleshooting* to analysis and solution of operational problems at an activated sludge plant by solving the case history problem given in the lesson.
2. Recognize that the wastewater treatment facility must be viewed as a total system and that solids handling and laboratory operational problems must be identified and solved before the operational problems with the activated sludge process can be corrected.
3. Recognize that modifications to the physical plant may be required if the plant is to be operable and controllable by identifying the need to modify the return sludge system at the facility analyzed in the case history problem.
4. Describe how inexpensive air lift pumps can be fabricated and installed by plant personnel and used to provide operational flexibility in an existing wastewater treatment facility.

Instructional Approach: Trainee problem solving in four person work groups and discussion of trainee findings.

Lesson Schedule: The 60 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 15 minutes	Introduce the Problem
15 - 35 minutes	Trainees Work on Problem
35 - 50 minutes	Report Trainee Findings
50 - 60 minutes	Present Solution Implemented by Plant Personnel

Trainee Materials Used in Lesson:

1. *Trainee Notebook,* pages T11.11.1 - T11.11.6, "Activated Sludge Process Troubleshooting, Hamsborough Case History."

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 11.11.1 - 11.11.7 , Unit 11, Lesson 11.
2. *Trainee Notebook*, pages T11.11.1 - T11.11.6, "Activated Sludge Process Troubleshooting, Hamsborough Case History."
3. Slides 179.2/11.11.1 - 179.2/11.11.23.

Instructor Material Recommended for Development: None

Additional Instructor References: None

Classroom Set-Up: As specified in Unit 11, Lesson 7.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Problem (15 minutes)	
A. Present the Hamsborough Situation	
1. The problem and a schematic flow diagram is provided in the *Trainee Notebook* as pages T11.11.1 - T11.11.6.	Refer class to *Trainee Notebook*, pages T11.11.1 - T11.11.6, "Activated Sludge Process Troubleshooting, Hamsborough Case History"
2. Discuss the problem statement	
a. Assume that this is the first visit that you are making to the plant and that it is a routine client contact visit.	Use Slide 179.2/11.11.1 Slide 179.2/11.11.1 is a blank
b. Note your reaction as a tour is made through the plant simulated by the following slides.	
3. Plant tour	
a. This shows the rectangular primary clarifier. Note that digester supernatant returns to the head of the plant. The clarifier contents are black.	Use Slide 179.2/11.11.2 Slide 179.2/11.11.2 is a photograph of the primary clarifier.
b. This is a roughing filter, a meat packing plant in the background used to discharge high strength wastes to the plant and this filter was used as a means of reducing the load. The filter is still in use.	Use Slide 179.2/11.11.3 Slide 179.2/11.11.3 is a photograph of the roughing filter.
c. The plant is an FMC rapid bloc plant. The aeration basin and clarifier have a common wall. Return sludge returns from the bottom of the clarifier to the aerator through a chimney. The operator is clearing the chimney with an air purge. This is done two or three times a day. Waste sludge is pumped through three air lift pumps; one is at the right of the	Use Slide 179.2/11.11.4 Slide 179.2/11.11.4 is a photograph of the aeration basins showing the operator clearing the return sludge chimneys.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
operator. Note the black color in the final clarifier.	
d. The cross section of the rapid bloc system is shown. Describe how the sludge return system works.	Use Slide 179.2/11.11.5 Slide 179.2/11.11.5 is a schematic of the rapid bloc process in cross-section.
e. This shows an operator replacing socks on the diffuser, a frequent task.	Use Slide 179.2/11.11.6 Slide 179.2/11.11.6 is a photograph showing an operator changing diffuser socks.
f. This is a closer shot of the surface of the aeration basin. Note the dark color and the crisp white foam.	Use Slide 179.2/11.11.7 Slide 179.2/11.11.7 is a photograph showing the aeration basin mixed liquor which is very dark brown and has a thin layer of crisp white foam.
g. Waste sludge is measured through a Parshall flume. Air lifts operate three minutes every hour on a time clock basis and return sludge to the primary clarifier. Note color of waste sludge.	Use Slide 179/2/11.11.8 Slide 179.2/11.11.8 is a photograph showing the waste sludge metering flume filled with black, shiny sludge.
h. The settleometer reading is taken for control purposes. This is the settleometer at time 0.	Use Slide 179.2/11.11.9 through 179.2/11.11.12 Slide 179.2/11.11.9-settling time 0
i. Settling after five minutes	Slide 179.2/11.11.10 - 5 minute settling
j. Settling after thirty minutes	Slide 179.2/11.11.11 - 30 minute settling
k. Settling after sixty minutes	Slide 179.2/11.11.12 - 60 minute settling
II. Trainees Analyze Hamsborough and Solve the Problem (20 minutes)	Use Slide 179.2/11.11.13 Slide 179,2/11.11.13 is a blank
A. Have trainees work in groups. Should discuss problem and recommend solutions.	Note: Trainees should work in groups. Trainees should be seated with pre-determined four-person groups.

LESSON OUTLINE | KEY POINTS & INSTRUCTOR GUIDE

B. The instructor plays the role of the operator and doesn't volunteer any information but does clarify questions asked by the trainee if the information is available to the instructor. The point should be stressed that the plant has a two-stage anaerobic digester with sand-drying beds. The plant has not drained digested sludge to the drying beds in over three months. Both digesters are full and every time the primary sludge is pumped to the digesters, an equal volume of thick supernatant is returned to the primary clarifier. Odors, however, are minimal.

   1. Trainees should work in groups of four and use the troubleshooting approach.

   2. Trainee groups should identify potential problems and recommend solutions.

III. Trainees Report Findings (15 minutes)

A. The following problems should have been identified by the class. Listen to their response and then fill in any that are missing prior to going on to the rest of the presentation.

   1. Improper digester operation causing imbalance in the activated sludge system.

   Encourage discussion of work group findings.

   2. Inability to measure and control return sludge rates.

   3. Inability to effectively waste solids because of the digester problem.

   4. An old inert activated sludge.

   5. Excessive chlorine use.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
6. Improper laboratory and reporting procedures.	
B. Have the class recommend their solutions to these problems.	Guide: Stress discussion between the trainee groups.
IV. The Hamsborough Solution Implemented	
A. Note that the following solutions were actually attempted at the plant.	
1. Emply and clean the digester.	
2. Increase solids wasting.	
3. Provide a sludge return system which was controllable.	
4. Correct laboratory deficiencies.	
5. The return sludge system recommended was an air lift system since this was least costly for the plant. The slides will illustrate the airlift system installation.	
B. Show the solutions in the slide series.	
1. The aerator was drained and the RAS chimneys are shown on the left.	Use Slide 179.2/11.11.14 Slide 179.2/11.11.14 is a photograph of the empty aeration basin.
2. The chimneys were blocked, only one side of the plant was converted at first to be able to use the other side as control.	Use Slide 179.2/11.11.15 Slide 179.2/11.11.15 is a photograph showing the operator blocking the return sludge chimney.
3. Airlifts were installed at a cost of approximately $2,400. Plant personnel did the work.	Use Slide 179.2/11.11.16 Slide 179.2/11.11.16 is a photograph showing plant personnel installing airlift pump in the final clarifier.
4. Airlift is shown installed in the hopper of the clarifier. The total depth is 18 feet. Later a T was added at the bottom.	Use Slide 179.2/11.11.17 Slide 179.2/11.11.17 is a photograph showing the airlift pump in the final clarifier.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
5. This shows another view of the airlift. Note the air line on the side (perhaps a sketch of a typical airlift would be helpful here using a blackboard).	Use Slide 179.2/11.11.18 Slide 179.2/11.11.18 is a photograph of the airlift pump in the final clarifier.
6. Airlifts in operation. These were controllable between 30 and 70 gpm discharge from each airlift.	Use Slide 179.2/11.11.19 Slide 179.2/11.11.19 is a photograph showing the six return sludge airlifts in operation.
7. Airlift flow rate was measured by using a calibrated bucket and stop watch. Later measuring flumes were added to the return sludge flow.	Use Slide 179.2/11.11.20 Slide 179.2.11/11.20 shows technical assistance personnel demonstrating the calibrated bucket flow meter.
8. Sludge collected in the ends of the hoppers. A flange on the end of a rope was used to stir up the settled sludge in the ends of the hoppers. No significant plugging was encountered in the pump system. Subsequently "Ts" were placed on the ends of the airlifts and eliminated this problem.	Use Slide 179.2/11.11.21 Slide 179.2/11.11.21 is a photograph showing an operator "dragging" the final clarifiers.
9. Final effluent is shown here. After the total plant was converted to airlifts, the effluent exceeded the lower NPDES requirements.	Use Slide 179.2/11.11.22 Slide 179.2/11.11.22 is a photograph showing a good clear final effluent.
C. Credit this problem to Mr. Owen Boe, U.S. EPA Region 8, O & M Section, Denver, Colorado. Mr. Boe is now with Envirotech Corporation.	Use Slide 179.2/11.11.23 Slide 179.2/11.11.23 is a blank

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 11: Hamsborough Case History

Trainee Notebook Contents

Hamsborough Case History T11.11.1
Flow Schematic: Hamsborough Treatment Plant . . . T11.11.3
Hamsborough Treatment Plant Data T11.11.4

Hamsborough Case History

You, as newly appointed Director of Technical Services, are preparing to inspect the Municipal wastewater treatment plant at Hamsborough. The plant expansion was designed by your firm several years ago. As your first step, you search through your files but can find only limited information on the facility; there have been no recent visits to the Hamsborough facility. However, by digging further into the files you do find some information on the community and the plant.

Hamsborough is a small suburban community with a population of about 15,000 with some light industry, mostly trucking and warehousing operations. There are two significant industrial dischargers to the system, a small printing plant which specializes in novelty printing and a meat processing and packaging plant.

A schematic flow diagram of the Hamsborough Wastewater Plant is shown as page T11.11.3. The major plant units are: a primary clarifier, followed by a single stage high rate trickling filter, followed by a complete mixing activated sludge plant with final clarifiers (a Chicago Pump Rapid Bloc Plant), and a chlorination system for disinfecting the final effluent. Two stage anaerobic digesters are used to handle all the sludge removed from the treatment facilities.

The original treatment plant consisted only of the primary clarifier and a trickling filter. Due to high organic loads from the meat packing plant, the design hydraulic loading is 2.1 MGD but the design population equivalent is 45,000. In the last few years the packing plant has become mainly a meat processing operation and the wastes received from the plant carry much less organic material than was previously received. The meat processing plant has its own pretreatment system which removes most of the solids and grease before the sewage enters the treatment facility.

At the treatment site the primary treated meat processing wastes combine with the raw sewage from Hamsborough and then enter the primary treatment units. The primary clarifier is a rectangular tank approximately ninety feet long and forty feet wide. Primary sludge is scraped along the bottom of the tank to the head end where it is collected into a sludge hopper. Sludge is then pumped to the primary digester. Waste activated sludge, which includes trickling filter solids since there is no intermediate clarifier, also enters the primary clarifier and is pumped with the primary sludge to the primary digester. Supernatant from the digesters and underflow from the drying beds is returned to the primary clarifier. Digested sludge is pumped out to the drying beds.

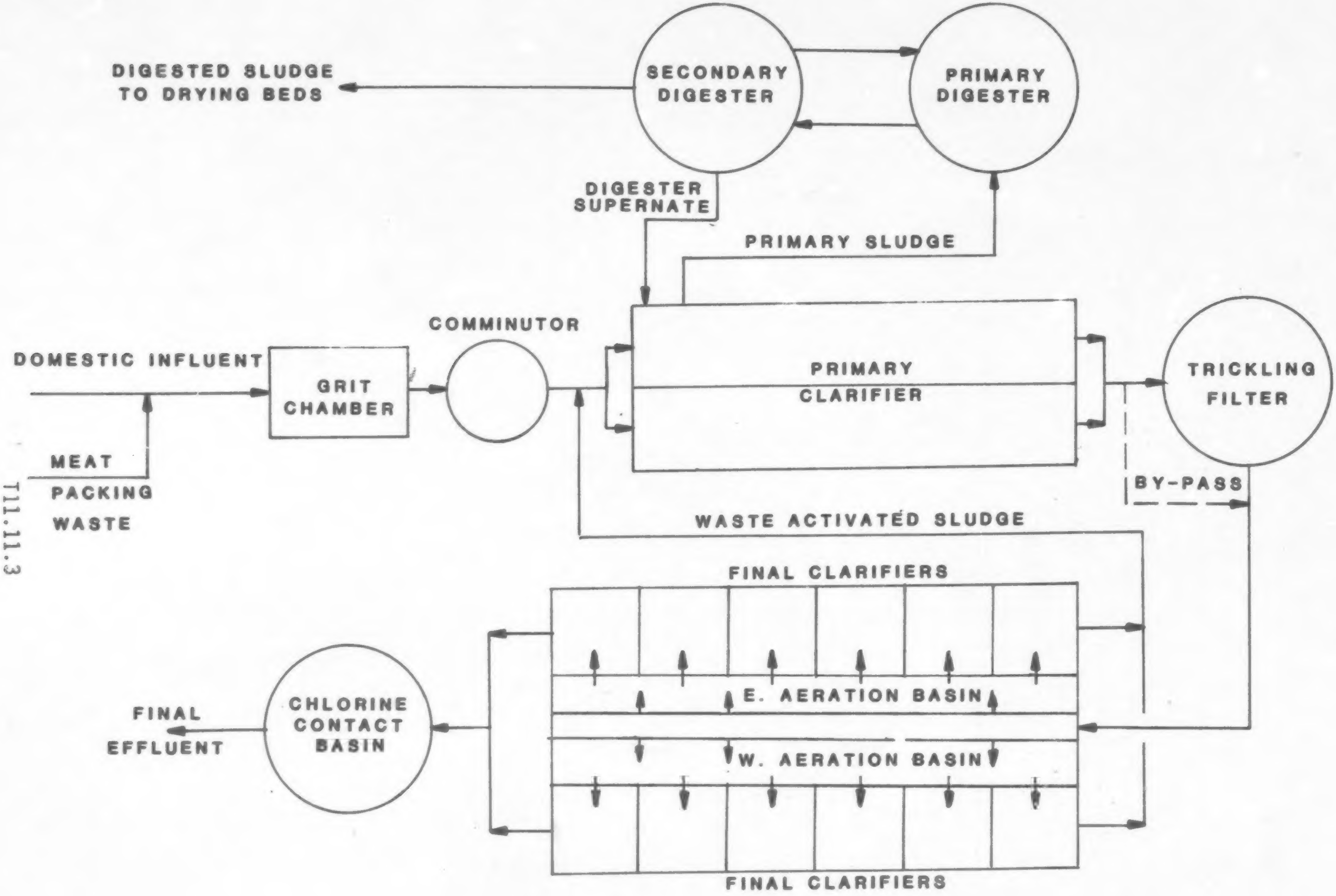
Effluent from the primary tank is pumped to a trickling filter. A portion of the trickling filter effluent is returned back to the wet well and is recycled through the filter. The flow pumped to the trickling filter is held at a constant rate by regulating the amount of filter effluent entering the wet well.

The trickling filter effluent not recirculated to the wet well enters the aeration system. There are essentially two identical activated sludge treatment units, and the flow is split between the east unit and the west unit. The aeration system is the high-rate complete mixing activated sludge "rapid-bloc" process. The aeration tank and final clarifiers have a common wall. Activated sludge enters the final clarifiers through ports between the clarifiers and aeration tanks. There are three airlift pumps for each unit to waste excess sludge. The settled activated sludge in the clarifiers is returned through a chimney type opening to the aeration basin. The driving force for the return sludge is primarily due to the upward lift action of the air diffusers in the adjacent aeration tanks - a principle much like that of an airlift pump.

Clarified treated sewage passes over the weirs of the clarifiers to the effluent troughs and into a chlorine contact basin. The chlorine contact basin is a converted primary clarifier. Chlorine is introduced into the inlet pipe just prior to the introduction to the clarifier. The solids scraping mechanism of the clarifier is still intact. Disinfected sewage overflows the weirs, enters the discharge pipe and is discharged into Hamm Creek.

You are particularly interested in visiting the plant because the Hamsborough Sanitary District is negotiating with other districts to form a joint authority and construct a new regional plant which will treat about 20 MGD sewage flow. Your firm is one of several being considered to design the new regional facility. You are visiting Hamsborough Plant to reestablish contact with plant personnel.

Your instructor will guide you through the facility by showing you a series of slides taken at the plant.



T11.11.3

FLOW SCHEMATIC: HAMSBOROUGH TREATMENT PLANT

During your visit to the Hamsborough Treatment Plant you observe the following:

The primary clarifier contents look black and septic. When primary sludge was pumped to the digesters (a time clock operation), it appeared that an equal volume of digester supernatant was returned to the primary clarifier. The supernatant return was deep black, shiny and appeared to have a very high solids content. The primary clarifier effluent was a dark, almost black color, and very turbid.

The stones on the trickling filter showed minimal growth. The filter effluent looked much like influent.

Hydraulic loading to the aeration basins appeared to be equally split to the two sides of the system. There is no way to measure the actual flow to each basin.

The aeration basins are a dark brown. There is a thin layer of crisp, white foam. The diffused air system appears to provide adequate mixing. During peak loads the D.O. in the aeration basin falls to values less than 1.0 mg/l. When this happens the operator turns on a third blower (two blowers are normally operated). With the third aerator, D.O. can be maintained between 1.0 and 2.0 mg/l.

The final clarifiers have a considerable amount of septic sludge floating on top of them. The process relies on a lifting effect from the aeration system to pull sludge through a chimney from the bottom of the clarifier. You suspect that the chimney is plugging. You note that the operators routinely blow air through the chimneys in an effort to clean out blocked sludge. This disrupts the plant effluent for a period of time until all septic and non-settling sludge is either washed over the weirs or finally settled again in the clarifiers. When black sludge was released from the bottom many small white worms were observed in the material.

A sample of the aeration basin mixed liquor was collected and a settleometer test run. The results of this test are summarized below.

TIME (min)	SETTLED SLUDGE VOLUME (ml)
0	1,000
5	180
10	160
15	155
20	150
30	150
60	140

T11.11.4

Visual observations made during the settling test included: black sludge solids, very granular sludge leaving turbid supernatant, considerable quantity of "ash" floating on surface, and unidentified white worms in the settled sludge.

Final clarifier effluent turbidities were greater than 10 JTU. Return sludge samples could not be collected.

Waste sludge was removed from the final clarifier by airlift pumps which run about 3 minutes per hour. Waste sludge flow is metered and then fed to the primary clarifier. Waste sludge flow averaged about 10,000 gpd. Centrifuge spins of waste sludge are in the range 13 - 18%. (Note that waste sludge is collected in hoppers in the final clarifiers and removed from the hoppers by the airlift pumps. Hence, the waste sludge may not be representative of the return sludge to the aeration basin.)

The old primary clarifier, which was converted for use as a chlorine contact basin, has the scraper and sludge collection and removal mechanisms in place. These are frequently operated to remove solids from the chlorine contact basin. Effluent Cl_2 concentrations are about 0.5 mg/l. Chlorine is being fed at the rate of 20 - 25 mg/l. Detention time in the basin is about 2 hours. The final effluent is clear with low turbidity and has little or no color.

Composite samples of final effluent are collected automatically from the chlorine contact basin overflow weir channel. Effluent BOD and suspended solids are run five times per week. While observing the test procedure, you note that the BOD samples were not dechlorinated. In talking with the laboratory technician you also learn that he reports volatile suspended solids on the effluent quality report he submits to the State. Consequently you estimate that the reported values are probably 30 - 50% lower than the actual values.

These are data which were submitted to the state during the last six months.

		Flow, MGD		BOD_5	TSS	Cl_2
Month	Avg.	Max.	Min.	mg/l	mg/l	mg/l
September	2.12	2.55	1.83	--	13	0.4
October	2.14	2.52	1.84	14	19	0.5
December	1.59	1.87	1.23	8	18	0.5
January	1.80	2.25	1.30	7	20	0.5
February	1.70	1.83	1.52	7	14	0.5
March	1.63	1.74	1.48	12	19	0.5

Inspection of the digesters shows that both digesters were filled to capacity. The sand drying beds are clean and do not appear to have been used for several months.

The Superintendent is aware that the State is beginning to enforce NPDES discharge limits aggressively. A primary target for enforcement are discharges to Hamm Creek. The Superintendent tells you that on July 1, the discharge limits in the NPDES permit will be lowered to 10 mg/l BOD_5 and 12 mg/l TSS. He is concerned that the plant cannot consistently meet the lower limits. He asks if you would be interested in a small contract to evaluate the system and recommend changes which may improve the performance of the plant and help him meet the permit limits. You accept.

Now What??

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 12: Sludge Settling Problems

Lesson 12 of 14 lessons Recommended Time: 120 minutes

Purpose: Many activated sludge process control problems result in an inability to separate and concentrate the mixed liquor suspended solids in the final clarifier. There are numerous causes of settling and concentration problems in the final clarifier. The troubleshooter must be able to identify and distinguish between the different sludge settling problems, identify the probable cause of the problem and recommend appropriate corrective actions. This lesson focuses on the final clarifier portion of the activated sludge system and provides the trainee tools for evaluating final clarifier settling problems and recommending corrective actions.

Trainee Entry Level Behavior: The trainee should have achieved the learning objectives for Unit 11, Lessons 1 - 11 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. List from memory four major classes of sludge settling problems as follows:

    a. Poor floc formation
    b. Poor compaction
    c. Low density
    d. Final clarifier hydraulic and/or physical problems

2. Define bulking as a sludge which settles very slowly or does not compact and is usually associated with SVI greater than 200.

3. For each settling problem listed below, state, using references, the probable cause or causes, procedures to identify causes and operational responses to cure the problem.

    a. Final clarifier hydraulic and/or physical problems
    b. Rising sludge
    c. Anaerobic sludge
    d. Over-aerated sludge
    e. Floating sludge
    f. Dispersed growth
    g. Deflocculation
    h. Pin-floc
    i. Straggler floc
    j. Non-filamentous bulking
    k. Filamentous bulking

4. Using references, explain how settleometer test results can be used to estimate solids settling flux and final clarifier total solids flux as a tool to identify final clarifier solids overloading as the probable cause of clarifier solids separation problems.

Instructional Approach: Illustrated lecture, trainee discussion and trainee problem solving.

Lesson Schedule: The 120 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 2 minutes	Introduction
2 - 10 minutes	Define Bulking
10 - 45 minutes	Settling Problems Caused by Final Clarifier Defects
45 - 75 minutes	Identify Non-bulking Settling Problems, Causes and Cures
75 - 90 minutes	Identify Classic Sludge Bulking and Possible Causes
90 - 105 minutes	Preventing and Curing Bulking
105 - 120 minutes	Discussion

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T11.12.1 - T11.12.6, "Final Clarifier Settling Problems."

2. *Trainee Notebook*, pages T11.12.7 - T11.12.16, "Estimating Final Clarifier Solids Handling Capacity."

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 11.12.1 - 11.12.47, Unit 11, Lesson 12.

2. Slides 179.2/11.12.1 - 179.2/11.12.54.

Instructor Materials Recommended for Development: None.

Additional Instructor References:

1. Pipes, W. O., "Bulking of Activated Sludge," *Advances in Applied Microbiology*, 9, 185-234 (1967).

2. Dick, R. I., "Role of Activated Sludge Final Settling Tanks," *Journal of the Sanitary Engineering Division, American Society of Civil Engineers*, 96(SA2), 423-436 (April, 1970).

3. Camp, T. R., "Sedimentation and the Design of Settling Tanks," *Transactions American Society of Civil Engineers*, 111, 895 (1946).

4. Bryant, J. O., *Continuous Time Simulation of the Conventional Activated Sludge Wastewater Renovation System*, Ph.D. Dissertation, Clemson University, Clemson, South Carolina (August, 1972).

5. Dick, R. I., "Folklore in the Design of Final Settling Tanks," *Journal Water Pollution Control Federation*, 48, 633-644 (April, 1976).

Classroom Set-Up: As specified in Unit 11, Lesson 1.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	Use Slide 179.2/11.12.1 Slide 179.2/11.12.1 is a blank
I. Introduction (2 minutes)	
A. Many activated sludge problems appear as excess solids in the effluent. B. There are many different situations that can cause effluent TSS to be high. C. Each cause of excess TSS calls for a different response by the troubleshooter or operator. D. The troubleshooter's ability to recognize the type of settling problem and recommend correct responses are among the most important skills he/she possesses.	Introduction should lay ground for discussion of a variety of settling problems and stress importance of being able to differentiate between settling and final clarifier problems
II. Define Sludge Bulking (8 minutes)	Use Slide 179.2/11.12.2 Slide 179.2/11.12.2 is a word slide which reads:
A. Define Bulking 1. Use Slide 179.2/11.12.2 to define sludge bulking. 2. Bulking is often defined as any sludge settling problem. This is incorrect. A bulking sludge is one which does not settle. There are many settling problems that are not bulking.	"Bulking Sludge Settles very slowly and does not compact. Sludges having SVI > 200 are usually classed as bulking sludges."
3. Use Slide 179.2/11.12.3 to illustrate a bulking sludge.	Use Slide 179.2/11.12.3 Slide 179.2/11.12.3 is a photograph showing a bulking sludge breaking the final clarifier liquid surface
B. Normal Sludge 1. Use Slide 179.2/11.12.4 to review characteristics of a normal or good sludge.	Use Slide 179.2/11.12.4 Slide 179.2/11.12.4 is a word slide which reads: "Normal Sludge

LESSON OUTLINE

2. Contrast normal sludge to bulking sludge

   a. Normal sludge SVI < 200, 75 < SVI < 125 preferred range.

   b. Bulking sludge has SVI > 200.

   c. Bulking sludge may have large number of filamentous organisms with few stalked or free swimming ciliates.

   d. Some cases of bulking not associated with filamentous organisms.

   e. A normal sludge will be the frame of reference for comparing other sludges that are abnormal.

C. Sludge Quality

   1. Use Slide 179.2/11.12.5 to compare good and bad sludge quality.

   2. Good quality produced by a normal sludge.

   3. Poor quality by an abnormal sludge.

   4. There may be no supernate or very small amounts of supernate with poor quality sludge.

KEY POINTS & INSTRUCTOR GUIDE

Few short filaments
Organisms present include:
   Bacteria
   Protozoa
   Free-Swimming Ciliates
   Stalked Ciliates
   Nematodes
   Rotifers
   Crustaceans
   Insects
Flocculant
Produces Clear Effluent"

Bulking will be discussed in more detail later in the lesson

Use Slide 179.2/11.12.5
Slide 179.2/11.12.5 is a word slide which reads:

"Settleable Solids Sludge Quality

GOOD
- Settles Rapidly
- Concentrates Uniformly in 30-60 Minutes
- Flocculant
- Clear Supernate
- Deep Tan to Brown

BAD
- Settles Very Fast or Very Slowly
- Concentrates Very Rapidly (< 30 Minutes) or Very Slowly (> 2 Hours)
- Granular or Excessively Fluffy
- Cloudy, Turbid, Straggler Floc, Pin Floc, Ash
- Light Tan, Very Dark or Black"

LESSON OUTLINE

5. Use Slide 179.2/11.12.6 to illustrate and contrast normal and abnormal sludges.

   Although these are schematics, they give a pretty good idea of what would been seen under the microscope.

D. Types of Sludge Settling Problems

1. Use Slide 179.2/11.12.7 to briefly review classification of sludge settling problems.
2. Inform class that *Trainee Notebook*, pages T11.12.1 - T11.12.6 summarizes key points from the discussion on sludge settling problems.
3. Lesson will discuss each class of settling problem looking at causes and cures for each class of problem.

III. Settling Problems Caused by Final Clarifier Defects (15 minutes)

A. Billowing Sludge Defined

1. Sludge settles well in laboratory settling test.
2. SVI in normal range of 75 - 125.
3. Solids billow up in final clarifier causing excess effluent suspended solids. Really solids washout.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.12.6

Slide 179.2/11.12.6 is a schematic sketch of normal, dispersed and filamentous bulking sludge floc particles with verbal description of major characteristics of each floc particle.

Use Slide 179.2/11.12.7

Slide 179.2/11.12.7 is a word slide which reads:

"Sludge Settling Problems

1. Final Clarifier Physical Problems

2. Low Density
   Rising Sludge
   Anaerobic Sludge
   Overaerated Sludge

3. Poor Floc Formation
   Dispersed Growth
   Deflocculation
   Pin-Floc
   Straggler Floc

4. Poor Compaction
   Zoogleal Bulking (Non-filamentous)
   Filamentous Bulking"

Use Slide 179.2/11.12.8

Slide 179.2/11.12.8 is a word slide which reads:

"Final Clarifier Physical Problems

Billowing Sludge"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
4. Billowing is not a sludge quality problem.	Use Slides 179.2/11.12.9 and 179.2/11.12.10 Slides 179.2/11.12.9 and 179.2/11.12.10 are photographs which illustrate billowing sludge in the final clarifier.
5. Use Slides 179.2/11.12.9 and 179.2/11.12.10 to illustrate the billowing sludge problem. Note the coarse, grainy texture of the sludge compared to the smooth texture of the bulking sludge photograph.	
B. Causes of Billowing	
1. Ask class to list possible causes of billowing.	Promote discussion.
2. Direct class toward the following minimum list of possible causes for the billowing sludge problem.	
a. Hydraulic Overload	
b. Poor Clarifier Design 1) Short circuiting 2) Inadequate weir length 3) Improper weir placement 4) Inadequate clarifier depth 5) Poor collector placement	
c. Poor Clarifier O & M 1) Inadequate sludge pumping 2) Plugged inlets and outlets 3) Unlevel weirs a) Within a tank b) Between two tanks 4) Plugged sludge collectors 5) Missing flights	
d. Excessive Solids Loading	
3. Use Slide 179.2/11.12.11 to summarize possible causes of billowing sludge in the final clarifier.	Use Slide 179.2/11.12.11 Slide 179.2/11.12.11 is a word slide which reads:

LESSON OUTLINE

4. Using Slide 179.2/11.12.11, have class discuss possible corrective actions.

   a. Hydraulic Overload

      1) Reduce return flow
      2) Put additional clarifiers into service
      3) By-pass???
      4) Flow equalization
      5) Check distribution to multiple clarifiers

   b. Poor Clarifier Design

      1) Short Circuiting
         a) Modify inlet structures
            1. Add target baffles
            2. Add other velocity control devices
         b) Reduce hydraulic loading
         c) Check weirs and level if needed
         d) Remove or block excess weirs

KEY POINTS &
INSTRUCTOR GUIDE

"Possible Causes of Billowing Sludge

1. Hydraulic Overload
2. Poor Clarifier Design
   a. Short Circuiting
   b. Inadequate Weir Length
   c. Improper Weir Placement
   d. Inadequate Clarifier Depth
   e. Poor Collector Placement
3. Poor Clarifier O & M
   a. Inadequate Sludge Pumping
   b. Plugged Inlets and Outlets
   c. Unlevel Weirs
      1) In One Tank
      2) Between Tanks
   d. Plugged Sludge Collectors
   e. Missing Flights
4. Solids Overloading"

Refer class to *Trainee Notebook*, handout page H11.7.5-H11.7.7 for a summary of final clarifier design and O & M factors which may affect activated sludge system performance.

LESSON OUTLINE | KEY POINTS & INSTRUCTOR GUIDE

   e) If multiple tanks are used, place effluent weirs at equal elevations.
   f) Check for thermal stratification.

2) Inadequate Weir Length
   a) Check weir loading. Should be less than 10,000 gpd/ft.
   b) Too little weir length can cause high upward velocity near the weir.
   c) Add weirs if needed.
   d) Reduce hydraulic loading.

3) Improper Weir Placement
   a) Excess weir length in one section of the tank causes localized velocity. Block or remove.
   b) Weirs too close to wall cause localized velocity currents.
      1. Move weirs away from wall.
      2. Block offending weir.
   c) Weirs should cover final third of clarifier surface and should never be closer than 4-5' to the clarifier wall.
   d) Common practice is to use clarifier launders with a weir plate on each side of the launder. Many launders are only 12-18" wide. The "double" wier acts as a single weir plate. Such double weir launders should be considered as a single weir when evaluating adequacy of weirs.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

4) Shallow Clarifier
    a) Add clarifiers to service.
    b) Reduce hydraulic load.
    c) Operate with low sludge blanket.
    d) Ten feet should be considered as a minimum final clarifier depth.

5) Poor Collector Placement
    a) May have to "squeegee" hopper bottom clarifiers.
    b) Add collectors to cover total clarifier bottom.
    c) Add flexible "squeegee" to end of collector arm to prevent sludge accumulation at the wall.
    d) Increase sludge pumping rate to prevent solids accumulation if the clarifier is not hydraulicly overloaded.

c. Poor Clarifier O & M

1) Inadequate sludge pumping
    a) Increase sludge pumping rate. Beware of possible clarifier overload.
    b) Check for plugged or inoperable sludge pumps. Repair or replace.

2) Plugged inlet and outlet structures.
    a) May cause short circuiting.
    b) Check and clear.

3) Unlevel weirs
    a) May cause short-circuiting or hydraulic overload on one clarifier when multiple clarifiers are used.
    b) Check and level weirs.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

4) Plugged collectors or missing flights
   a) May cause solids accumulation in clarifier.
   b) Check and repair collector systems.

d. Solids Overloading

1) Rule of thumb for solids loading:

   a) If SVI > 125 ml/gm, then solids loading should be less than 30 $\text{lbs/ft}^2\text{/day}$.

   b) If SVI < 125 ml/gm, then solids loading should be less than 80 $\text{lbs/ft}^2\text{/day}$.

2) Rules of thumb may get you in trouble. Next section will discuss technique to evaluate final clarifier solids handling capacity.

3) If problem is solids overload, then

   a) Add clarifiers to service.
   b) Change process to produce a faster settling sludge.
      1. Reaerate sludge
      2. Increase MCRT
      3. Decrease F/M
      4. Beware of other problems which may result.

C. Procedure to Estimate Final Clarifier Solids Handling Capacity (15 minutes)

Refer class to *Trainee Notebook*, pages T11.12.7 -T11.12.16.

1. Solids Movement Mechanisms in Final Clarifier

Use Slide 179.2/11.12.12

Slide 179.2/11.12.12 is a word slide which reads:

a. Solids settling

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
1) Removal resulting from solids downward movement relative to the liquid in the final clarifier.	"Final Clarifier Solids Removal Mechanisms · Solids Settling · Bulk Transport"
b. Bulk Transport	
1) Solids downward movement as a result of the total final clarifier hydraulic underflow. A physical phenomenon independent of solids settling.	
2) The total final clarifier hydraulic underflow is the sum of the waste activated and return sludge hydraulic flows.	
c. Total Solids Movement	
1) The sum of the movement resulting from solids settling relative to the liquid phase plus the bulk hydraulic transport in the total final clarifier underflow.	
2. Define Solids Flux	Use Slide 179.2/11.12.13 Slide 179.2/11.12.13 is a word slide which reads:
a. Flux	
1) The quantity of material passing through a unit area in a unit time.	"Solids Flux Flux - the quantity of material passing through a unit area in a unit time. Units - Pounds/square foot/hour"
2) Typical units are pounds/ft^2/hr.	
b. Bulk Transport Solids Flux	Use Slide 179.2/11.12.14 Slide 179.2/11.12.14 is a word slide which reads:
1) Using Slide 179.2/11.12.14, define the final clarifier bulk transport solids flux.	"Final Clarifier Bulk Transport Solids Flux

LESSON OUTLINE

2) Using Slide 179.2/11.12.14, give the formula for the final clarifier bulk transport solids flux.

   a) Final clarifier underflow velocity is the total final clarifier hydraulic underflow rate (waste plus return activated sludge) in ft^3/hr divided by the final clarifier surface area in ft^2.

   b) The solids concentration changes with depth in the final clarifier as a result of solids settling relative to the moving liquid.

      1. Solids enter the clarifier at the MLSS concentration, the ATC.

      2. Solids leave the clarifier at the underflow concentration, the RSC.

      3. Solids concentration in the final clarifier sludge blanket is not a linear function of clarifier depth.

3) Use Slide 179.2/11.12.15 to illustrate the final clarifier bulk transport solids flux as a function of solids concentration.

   a) Straight line passing through the origin.

KEY POINTS & INSTRUCTOR GUIDE

Definition

The quantity of solids carried through a unit area in a unit time by the final clarifier hydraulic underflow.

Formula

Bulk Transport Solids Flux ($lbs/ft^2/hr$) = Final Clarifier Underflow Velocity (ft/hr) x Solids Concentration (lbs/ft^3)"

Use Slide 179.2/11.12.15

Slide 179.2/11.12.15 is a graph of final clarifier bulk transport solids flux as a function of solids concentration

LESSON OUTLINE

b) Slope is equal to the final clarifier underflow velocity.

1. Increase the final clarifier underflow velocity and the bulk transport solids flux increases.

2. Decrease the final clarifier underflow velocity and the bulk transport solids flux decreases.

c. Solids Settling Flux

1) Use Slide 179.2/11.12.16 to define the solids settling flux.

2) Using Slide 179.2/11.12.16, discuss the formula for calculating the solids settling flux.

3. Determine Solids Settling Velocity

a. Perform laboratory settling test using MLSS sample.

1) Should use 6-8 foot tall laboratory solids settling column for best results.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.12.16
Slide 179.2/11.12.16 is a word slide which reads:

"Final Clarifier Solids Settling Flux

Definition
The quantity of solids which pass through a unit area in a unit time as a result of gravity settling

Formula
Solids Settling Flux (lbs/ft^2/hr) = Solids Settling Velocity (ft/hr) x Solids Concentration (lbs/ft^3)"

Use Slide 179.2/11.12.17
Slide 179.2/11.12.17 is a graph which illustrates the calculation procedure for determining solids settling velocity using solids settling test data. (Same as Figure T11.12.1, page T11.12.14 in the *Trainee Notebook*)

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2) Can estimate using settleometer or graduated cylinder test but settling velocities will be lower because of the limited depth of the settling test vessel.	
3) Explain the effect of settling column depth on test results.	Note: Laboratory settling test and calculation procedures are presented in Unit 11, Lesson 5.
a) In a 6 foot settling column the solids must settle 3 feet for the solids concentration to double.	
b) In a settleometer the solids concentration will double when the solids have settled only 0.25 feet.	
c) In a 1000 ml graduated cylinder the solids concentration will double when the solids have settled only 0.6 feet.	
b. Plot the SSV curve.	
c. The settling velocity is equal to the slope of the tangent to the SSV vs. SST curve.	
d. Calculate SSC values corresponding to the settling velocity.	
4. Calculate Solids Settling Flux	
a. Calculate the solids settling flux as the product of the solids settling velocity (ft/hr) times the solids concentration (lbs/ft^3).	
b. Plot solids settling flux as a function of SSC.	Use Slide 179.2/11.12.18

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	Slide 179.2/11.12.18 is a graph of a typical solids settling flux vs. solids concentration curve.
c. Discuss the solids settling flux curve	
1) Only the portion of the curve for SSC > MLSS concentration can be determined using the procedure described.	
2) The solids settling velocity decreases with increasing SSC.	
3) The product of solids settling velocity times solids concentration which is the solids settling flux has a maximum value. The maximum value will usually occur at a solids concentration less than the MLSS concentration.	
4) At low solids concentrations the solids settling flux decreases because solids concentration decreases faster than the solids settling velocity increases.	
5) Consequently, the solids settling flux curve has the characteristic shape shown in Slide 179.2/11.12.18.	
5. Determine the Total Final Clarifier Solids Flux	
a. Using Slide 179.2/11.12.19 21, describe how the total final clarifier solids flux is determined as the sum of the solids settling flux plus the bulk transport solids flux.	Use Slide 179.2/11.12.19 Slide 179.2/11.12.19 is a graph showing the final clarifier solids settling flux, bulk transport solids flux and total solids flux as a function of solids concentration.

LESSON OUTLINE

b. Point out that the total solids flux curve always has a minimum usually at solids concentration greater than the MLSS concentration.

6. Determine the Final Clarifier Limiting Solids Flux and Underflow Concentration

   a. Explain that the minimum in the final clarifier total solids flux corresponds to the limiting solids flux in the clarifier and determines the final clarifier solids handling capacity.

      1) Final clarifier solids handling capacity equals the product of the final clarifier limiting solids flux times the final clarifier surface area.

      2) If solids feed to the clarifier exceeds the clarifier solids handling capacity, solids accumulate in the clarifier and the sludge blanket rises.

      3) If the solids feed to the clarifier is less than the clarifier solids handling capacity, solids are removed from the clarifier and the sludge blanket falls.

   b. Explain how the curves are used to estimate the underflow solids concentration.

D. Factors Affecting Final Clarifier Solids Handling Capacity

KEY POINTS &
INSTRUCTOR GUIDE

Use Slide 179.2/11.12.20
Slide 179.2/11.12.20 is a graph showing the total final clarifier solids flux and bulk transport solids flux curves as a function of solids concentration with the tangent drawn to the minimum in the total solids flux curve. The solids concentrations at the limiting solids flux and underflow are noted on the graph.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
1. Effect of solids settling velocity	Use Slide 179.2/11.12.21 Slide 179.2/11.12.21 is a graph showing two solids settling flux and two final clarifier total solids flux curves with the same final clarifier underflow velocity as a function of solids concentration.
a. Use Slide 179.2/11.12.21 to show that increasing the solids settling velocity increases the solids settling flux and hence the final clarifier solids handling capacity.	
b. Lead class discussion on use of this information in troubleshooting.	
1) If final clarifier solids handling capacity is the problem, make process changes to increase solids settling velocity and hence final clarifier solids handling capacity.	
a) Increase solids inventory	Refer class to previous lessons which discuss process conditions which result in faster settling solids.
b) Increase solids aeration time	
2. Effect of final clarifier underflow velocity	Use Slide 179.2/11.12.22 Slide 179.2/11.12.22 is a graph showing total solids flux at two underflow velocities with the same solids settling flux.
a. Use Slide 179.2/11.12.22 to show that increasing the final clarifier underflow velocity increases the final clarifier solids handling capacity.	
1) Increasing underflow velocity increases solids handling capacity but produces a lower underflow solids concentration.	
2) Decreasing underflow velocity decreases solids handling capacity but produces a more concentrated underflow solids concentration.	
b. Lead class discussion on the use of this information in troubleshooting.	Emphasize secondary effects of changing final clarifier underflow velocity.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

1) Increase underflow velocity.
    a) Increases solids handling capacity.
    b) Increases hydraulic load to final clarifier.
    c) Creates process conditions which tend to produce slower settling sludge.
2) Decrease underflow velocity.
    a) Decreases solids handling capacity.
    b) Decreases hydraulic load on clarifier.
    c) Creates process conditions which tend to produce faster settling solids.

c. Stress point that final clarifier solids handling capacity is not constant but changes with operating conditions because:

1) Solids settling characteristics change.
2) Underflow velocity can be changed.
3) The operator can affect both solids settling characteristics and underflow velocity by changing the process conditions
4) Most designers are either unaware of this fact or choose to ignore it in plant design.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
E. Refer class to example problem on *Trainee Notebook* pages T11.12.12 - T11.12.16. Answer any questions concerning the example problem.	
IV. Non-Bulking Sludge Quality Related Settling Problems (15 minutes)	
A. Previous section emphasized physical conditions which may cause final clarifier settling problems. This section focuses on sludge quality related settling problems. Bulking *per se* will be discussed in the next section of the lesson.	Use Slide 179.2/11.12.23 Slide 179.2/11.12.23 is a word slide which reads: "Settling Problems Caused by Poor Sludge Quality · Non-Bulking · Bulking"
B. Problems Caused by Low Sludge Density 1. Use Slide 179.2/11.12.24 to briefly introduce sludge quality problems to be discussed under the topic low sludge density.	Use Slide 179.2/11.12.24 Slide 179.2/11.12.24 is a word slide which reads: "Low Sludge Density · Rising Sludge · Anaerobic Sludge · Over Aerated Sludge"
2. Rising Sludge a. Use Slide 179.2/11.12.25 and ask class to identify the problem, possible causes and corrective responses.	Use Slide 179.2/11.12.25 Slide 179.2/11.12.25 is a photograph showing sludge clumping in the final clarifier.
b. Answers sought 1) Problem a) Sludge rising in final clarifier b) Sometimes called clumping 2) Possible Cause a) Nitrification in the	

LESSON OUTLINE

aeration basin.
  - b) Denitrification in final clarifier.
  - c) Denitrification occurs under anoxic conditions. Thus sludge is probably staying in the clarifier too long.

3) Corrective Actions

  - a) Increase return sludge flow rate to decrease sludge detention time in final clarifier.
  - b) Increase aeration basin effluent D.O. concentration to keep sludge aerobic in the final clarifier.
  - c) Take system out of nitrification if nitrification is not desired.
    1. Reduce MCRT
    2. Increase F/M
    3. Decrease sludge aeration time

c. Use Slide 179.2/11.12.26 to summarize problem causes identified above.

d. Note that all sludges will rise if allowed to remain in anoxic conditions long enough.

  1) Rise time for a normal sludge is 2 - 4 hours.

  2) Highly nitrified sludge will rise in 1 hour or less.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.12.26

Slide 179.2/11.12.26 is a word slide which reads:

"Rising Sludge

Nitrification in the Aeration Basin

$NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$

Denitrification in the Final Clarifier

$NO_3^- \rightarrow NO_2^- \rightarrow N_2$

Anoxic Conditions in the Sludge Blanket"

3. Anaerobic Sludge

   a. Problem similar to rising sludge except that anaerobic decomposition of sludge occurs producing CO_2, CH_4, H_2 and H_2S which causes sludge to float.

   b. Anaerobic sludge clumps characteristically are black in color as contrasted to the light tan color of denitrified sludge clumps.

   c. Caused by sludge remaining in clarifier too long and going septic.

      1) Inadequate sludge pumping.

      2) Plugged RSF or WAS pumps.

      3) Plugged sludge collectors.

      4) Inadequate sludge collector spacing leaving dead spots.

      5) Sludge collector drive motors off because of overloading or overheating.

   d. Corrective Responses

      1) Increase sludge pumping to reduce clarifier sludge detention time.

      2) Increase aeration basin effluent D.O. CAUTION: This could promote nitrification in the aeration basin.

      3) Check clarifier for proper O & M and implement improved procedures.

Use Slide 179.2/11.12.27

Slide 179.2/11.12.27 is a word slide which reads:

"Anaerobic Sludge

Cause: Anaerobic Decomposition
in Final Clarifier

Cures: 1. Decrease Clarifier Sludge Detention Time
2. Increase Aeration Basin D.O.
3. Improve Clarifier O & M
4. Correct Clarifier Design Deficiencies"

Note: Clarifier design and O & M defects are discussed in the preceding section of this lesson.

LESSON OUTLINE

4) Correct clarifier design deficiencies.

   a) Add squeegees.
   b) Add sludge collectors.

4. Over Aerated Sludge

   a. Causes

      1) Sludge is over oxidized (over stabilized) reducing flocculation characteristics.

      2) Typical of extended aeration plants.

      3) Violent aeration ruptures floc particles by mechanical shear.

      4) Air bubbles trapped in sludge. Presence of excess grease promotes air bubble capture.

      5) Over oxidation or stabilization of sludge results in large quantity of cell debris and ash.

   b. Cures

      1) Reduce aeration rate if mixed liquor D.O. greater than 2.0 mg/l.

      2) Decrease solids inventory.

      3) Decrease sludge aeration time.

C. Problems Caused by Poor Floc Formation

   1. Use Slide 179.2/11.12.29 to introduce problems to be discussed.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.12.28
Slide 179.2/11.12.28 is a word slide which reads:

"Over Aerated Sludge

- Sludge is Overstabilized
- Trapped Air Bubbles
- Excess Grease Promotes Air Capture
- Mechanical Rupture of Floc
- Ash and Cell Debris"

Use Slide 179.2/11.12.29
Slide 179.2/11.12.29 is a word slide which reads:

LESSON OUTLINE

2. Dispersed Growth
    a. No flocculation or settling
    b. Short filaments, yeast cells, flagellated protozoans, dispersed bacteria cells
    c. Overloaded systems F/M > 2.0
    d. Plant start-up problem
    e. Not an activated sludge
    f. Usually caused by organic overload
    g. Corrective response is to increase solids inventory, reduce F/M, increase sludge aeration time
    h. Deflocculation may give a similar appearance in settling test.
3. Deflocculation
    a. Weak floc forms but is easily broken up
    b. Causes
        1) Shock loads
        2) Change in waste characteristics
        3) Toxic substances
        4) Extreme pH

KEY POINTS & INSTRUCTOR GUIDE

"Settling Problems Caused by Poor Floc Formation

- Dispersed Growth
- Deflocculation
- Pin Floc
- Straggler Floc"

Use Slide 179.2/11.12.30

Slide 179.2/11.12.30 is a word slide which reads:

"Dispersed Growth

No Flocculation or Settling
Contains Short Filaments, Yeast Cells, Flagellated Protozoans, Dispersed Bacteria
Characteristic of Overloaded Systems, F/M > 2.0
Frequently Encountered During Plant Start-Up
Not Considered to be a True "Activated Sludge""

Use Slide 179.2/11.12.31

Slide 179.2/11.12.31 is a word slide which reads:

"Deflocculation

Floc Breaks Up Easily
Causes
Shock Loads
Change in Waste
Toxic Substances
Extreme pH
Mechanical Shear"

LESSON OUTLINE

        a) pH < 5.0

        b) pH > 9.0

    5) Violent mixing of sludge floc

c. True deflocculation is usually the result of some factor which has caused a substantial "kill" of the sludge.

    1) Evaluation procedure

        a) Microscopic examination - check protozoans for activity.

        b) If not present or if encysted, suspect toxic load.

        c) Monitor influent RR. If drops suddenly, suspect toxic load.

    2) Use as key off for discussion of toxic discharge control.

        a) Identify possible sources

        b) Control sources or get warning from source if spill occurs.

        c) Consider diverting toxic load to protect system, preferably to holding basin. Basis: may be better to by-pass for short period rather than lousing up system for several weeks

        d) Note that deflocculation, dispersed growth or over aeration problems may give a similar appearance in the laboratory settling test.

KEY POINTS & INSTRUCTOR GUIDE

Refer class to *Trainee Notebook* handout pages H11.7.11-H11.7.12 for notes on procedures to handle toxic loads

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
4. Pin-Floc	
a. Use Slide 179.2/11.12.33 to introduce pin-floc problems.	Use Slide 179.2/11.12.33 Slide 179.2/11.12.33 is a photograph showing a final clarifier covered with "ash"
1) Describe pin-floc as a) Small floc particles (pin-point floc) which is not captured by sludge blanket. b) Pin-floc particles are stable and exert a low BOD.	
2) Note similarity to over-aeration problem using Slide 179.2/11.12.34.	Use Slide 179.2/11.12.34 Slide 179.2/11.12.34 is a photograph showing final clarifier sludge with turbidity outside effluent weir caused by pin-floc
b. Use Slide 179.2/11.12.35 to guide discussion of causes of pin-floc.	Use Slide 179.2/11.12.35 Slide 179.2/11.12.35 is a word slide which reads:
1) Old sludge problem a) Low F/M b) Long MCRT c) Long sludge aeration time d) High solids inventory	"Pin-Floc · Small Floc Particles Remain in Suspension · Stable, Low BOD Particles · Normally Associated with · Low F/M · Old Sludge · Long Sludge Aeration Time · Overaeration"
2) Associated with early stages of system entering into nitrification reaction phase. a) May be temperature related b) If temperature increases, then waste and sludge stabilization can occur with: 1. Lower solids inventory 2. Shorter sludge aeration time	

LESSON OUTLINE

3. Shorter aeration basin detention time

c) Higher temperatures promote nitrification.

3) Over-aeration may cause a similar problem.

a) Floc shear problem.

b) Cell debris or ashing may also be a problem.

c) MLSS having grease content greater than 15% seem to have more pin-floc problems than MLSS having less than 15% grease content.

c. Discuss corrective actions

1) Take system to full nitrification if necessary.

a) Higher oxygen demand in aeration basin.

b) Potential rising sludge problem.

c) Operate with very low or no sludge blanket in final clarifier.

d) May continue to have ashing problem. Therefore, need a good scum baffle and scum removal system on the final clarifier.

2) Take system out of nitrification

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.12.36 and 179.2/11.12.37

Slides 179.2/11.12.36 and 179.2/11.12.37 are photographs showing scum retention in the final clarifier and illustrate the importance of the final clarifier scum baffle.

LESSON OUTLINE

- a) Reduce solids inventory
- b) Increase F/M
- c) Decrease sludge aeration time
- d) Reduce aeration rate if over-aeration is the problem

5. Straggler Floc

   a. Use Slide 179.2/11.12.38 to introduce a discussion and description of straggler floc.

      1) Relatively large slow settling sludge particles which are not trapped by the sludge blanket.

      2) Straggler floc particles are relatively unstable and exert a high BOD.

   b. Use Slide 179.2/11.12.39 to guide discussion on the causes of straggler floc.

      1) Signals transition between normal sludge and young sludge condition.
         - a) Low solids inventory
         - b) Short MCRT

      2) Usually associated with slight organic overload conditions.
         - a) F/M higher than optimum
         - b) F/M near upper limits of normal range

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.12.38

Slide 179.2/11.12.38 is a photograph showing billows of straggler floc near the final clarifier effluent weir

Use Slide 179.2/11.12.39

Slide 179.2/11.12.39 is a word slide which reads:

"Straggler Floc

- ·Slow Settling Floc Particles
- ·Relatively Unstable, High BOD Particles
- ·Normally Associated With:
  - ·Slight Organic Overload
  - ·F/M Higher than Optimum
  - ·Younger Sludge
  - ·Low Solids Inventory
  - ·Short MCRT"

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

3) May be temperature related

   a) Decreasing temperature need more solids and/or longer aeration basin detention time to stabilize same applied load.

   b) At lower temperatures need longer sludge aeration time to stabilize sludge.

4) If trends toward younger sludge conditions continue, may lead to very slow settling young sludge (classic sludge bulking).

c. Discuss corrective actions

   1) Increase solids inventory

   2) Increase solids aeration time

   3) Decrease F/M

   4) Increase aeration basin detention time

V. Identify Classic Sludge Bulking and Possible Causes (15 minutes)

   A. Differentiate between filamentous and non-filamentous bulking.

Use Slide 179.2/11.12.40
Slide 179.2/11.12.40 is a word slide which reads:

"Bulking Sludges

·Filamentous
·Non-Filamentous"

      1. Classic sludge bulking, often called filamentous bulking, is usually associated with conditions under which filamentous organisms become predominant in the sludge.

         a. Large number of long filaments extend outward from the floc particles into the liquid phase.

LESSON OUTLINE | KEY POINTS & INSTRUCTOR GUIDE

b. Filaments create a bridging effect between floc particles causing interference with settling and compaction.

c. Filamentous bulking is often associated with young, understabilized sludge conditions which normally produce slow settling sludges.

2. Non-filamentous or zoogleal bulking occurs when the sludge flocculates but does not settle.

   a. Filamentous organisms are not present in excessive numbers.

   b. Floc is usually ragged and diffuse and has a large surface area.

   c. Non-filamentous bulking may be characterized as one of the poor floc formation phenomenon.

      1) Over-aeration

      2) Dispersed growth

      3) Deflocculation

         a) Toxic load

         b) Shock load

         c) pH effects

   d. Control responses and corrective actions are those given for the poor floc formation problems.

B. Filamentous Bulking

   1. Characteristics

      a. Excessive filaments

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. Settles very slowly and doesn't compact. SVI is greater than 200 ml/gm.	
c. Supernate is usually	Use Slide 179.2/11.12.41 and 179.2/11.12.42 Slides 179.2/11.12.41 and 179.2/11.12.42 are photographs of final clarifiers filled with filamentous bulking sludges
1) Very clear	
2) Very small volume produced very slowly	
3) Use Slide 179.2/11.12.41 to illustrate ability of bulking sludge to produce a very clear supernate.	
4) Use Slide 179.2/11.12.42 to illustrate problems of retaining bulking sludge in the final clarifier, i.e., the problem of a small volume of supernate produced very slowly.	
5) Not all filamentous bulking sludges produce clear supernate. Slide 179.2/11.12.43 shows a clarifier covered with thick foam. Such sludges usually contain large numbers of the branched filament Nocardia. May still get good effluent if the clarifier scum baffle and scum handling systems are good.	Use Slide 179.2/11.12.43 Slide 179.2/11.12.43 is a photograph of a final clarifier covered with a thick foam containing large numbers of Nocardia (a highly branched filamentous organism)
d. Except for the excessive numbers of long extended filaments, the sludge floc looks normal with filamentous bulking.	
2. Role of filamentous organisms	
a. Extended filaments interfere with settling causing slow settling rate	
b. Two theories on filament role:	

LESSON OUTLINE | KEY POINTS & INSTRUCTOR GUIDE

1) Filaments cause bulking

2) Filaments are only a symptom because aeration conditions favor filament growth over growth of a balanced normal sludge population.

Note: The course developers tend to favor the theory that the filamentous organisms are symtomatic of bulking conditions. However, there is no definitive evidence to favor one theory over the other

c. Most commonly encountered filamentous organisms in activated sludge systems are:

   1) Sphaerotilus natans

   2) Nocardia

   3) Thiothrix (a sulfur bacteria)

   4) Many other filamentous organisms have been found in activated sludges. Many fungi are filamentous.

3. Causes of Bulking

a. Effect of F/M

Use Slide 179.2/11.12.44

Slide 179.2/11.12.44 is a graph showing the variation of SVI with F/M for typical activated sludge plants

   1) F/M in range of 0.5 - 0.8 #BOD/#Solids/day produce slow settling sludges.

   2) Other F/M regions also tend to produce slower settling sludges ($0.1 < F/M < 0.2$).

   3) Slide 179.2/11.12.44 should be used as a guide only. Factors other than F/M impact settleability. Chief among these are:

      a) Waste characteristics

Note: These points will be addressed in detail in following sections of the lesson

         1. Stabilization time

         2. Nutrient balance

LESSON OUTLINE

3. Toxic substances

4. Septic sewage

b) Aeration conditions

1. Aeration basin hydraulic detention time

2. Sludge aeration time

3. Aeration basin D.O.

b. Effect of waste characteristics

1) Organic overload

a) High F/M tends to produce slow settling sludge. Control responses are:

1. Increase solids inventory.

2. Increase aeration detention time.

3. Increase solids aeration time.

b) Wastes containing a high proportion of soluble organics which stabilize readily tend to produce bulky sludges more readily than wastes which contain a large proportion of suspended or slowly stabilized organics. May be associated with nutrient imbalance problems. Control responses are similar to a) above if nutrients are not a problem.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.12.45

Slide 179.2/11.12.45 is a word slide which reads:

"Waste Characteristics Associated with Sludge Bulking

- Organic Overload
  - High Soluble Organic Concentration
  - Shock Loads
  - Temperature
- Nutrient Imbalance
  - BOD: N > 20:1
  - BOD: P > 100:1
  - P < 2 mg/l
  - C: N > 10:1
- Toxic Substances
- Septic Sewage
- Hydraulic Overload"

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

c) Shock loads may cause an organic overload or may cause deflocculation because sludge is not acclimated to the suddenly applied load. Control responses

1. Load equalization

2. Carry higher solids inventory in system

3. Use sludge reaeration

4. Sewer use control if an industrial source

d) At lower temperatures need a higher solids inventory and longer sludge aeration time to stabilize the applied load because biological activity decreases with decreasing temperature.

e) Organic overload creates aeration conditions which are more favorable to filamentous organisms permitting filament growths to become predominant in the activated sludge.

2) Nutrient Imbalance

a) Low nutrient concentrations encourage filamentous organisms at the expense of desired organisms.

1. Filaments may have lower nutrient requirements.

LESSON OUTLINE

2. Larger filament surface area may make filaments more able to compete for limited nutrients.

b) Nutrient deficiency may result in conditions in which sludge growth does not occur resulting in conditions similar to dispersed growth or deflocculation phenomena.

c) Following conditions have been associated with filamentous bulking:

1. BOD:N > 20:1

2. BOD:P > 100:1

3. P < 2 mg/l

4. C:N > 10:1

d) Control responses

1. Analyze for nutrients

2. Feed nutrients as needed

3. Digester supernate may be a source of N and P but may create other problems such as organic overload or septic sewage type conditions.

3) Toxic Substances

a) Nature of toxic load

1. Shock loads more difficult to handle

KEY POINTS & INSTRUCTOR GUIDE

Note: The Kraus modified activated sludge system was originally developed at Peoria, Illinois, to provide a nutrient supplement at a plant which treated a large portion of brewery, distillary and corn processing wastes

2. Sludge can be acclimated to many toxic substances if fed continuously at low levels

b) Some substances are toxic to all organisms and cause a no-growth phenomenon.

c) Some substances selectively toxic to filamentous organisms and may cause deflocculation to occur.

d) Control measures

1. Monitor influent for toxics; fed sludge RR is a good monitoring tool.

2. Divert toxics from aeration system if possible.

3. Source control may be needed.

4. Chemical precipitation of some toxics, such as heavy metals, may be possible in the preliminary or primary treatment units.

5. Use sludge reaeration to protect the activated sludge solids.

4) Septic Sewage

a) May be associated with organic overload type problem because solids may be solubilized in collection system.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b) Septic conditions "free" sulfur compounds and may promote thiothrix or Beggiatoa (sulfur bacteria) growths.	
c) Control responses:	
1. Correct collection system deficiencies.	
2. Preaerate sewage.	
3. Use Cl_2 or H_2O_2 to pretreate sewage.	
4. Digester or thickener supernates may be the source. Correct initial plant operating procedures.	
5) Hydraulic Overload	
a) Effects	
1. Hydraulic wash-out in the final clarifier.	
2. Reduced aeration detention time reducing time available to stabilize the waste thus producing conditions which promote growth of a slower settling sludge.	
b) May be accompanied by a shock organic overload if hydraulic flushing of the collection system occurs.	
c) Corrective responses	

LESSON OUTLINE

1. Flow equalization.
2. Increase aeration volume and final clarifier surface area by adding units to service.
3. Use sludge reaeration (contact stabilization) mode of operation to store and protect solids inventory.
4. Correct infiltration/inflow problems in the collection system if cost effective.

c. Aeration basin conditions

  1) pH

    a) Preferred range is 6 - 9.

    b) pH < 5 can cause deflocculation.

    c) Extended operation outside preferred ranges promote filamentous growths.

    d) Possible causes of extreme pH

      1. Influent waste.
      2. Internal recycles.
      3. Nitrification may cause pH to drop. Add alkalinity to maintain pH > 6.5.
      4. Alum as a coagulant cause pH to drop.

KEY POINTS &
INSTRUCTOR GUIDE

Use Slide 179.2/11.12.46
Slide 179.2/11.12.46 is a word slide which reads:

"Aeration Basin Conditions Associated with Filamentous Bulking

pH
Preferred Range: $6<pH<9$
Deflocculation at $pH<5$

Temperature

Dissolved Oxygen
Preferred Range: $1 mg/l< D.O.<3 mg/l$
Conditions Favor Filament Growth When:

D.O. < 1 mg/l
D.O. > 6 mg/l"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

a. Use caustic or soda ash to maintain pH.

b. Control alum addition rate to avoid severe pH drops.

2) Temperature

a) Increasing temperatures

1. Encourages nitrification.

2. Encourages filament growth.

3. Increases biological activity creating an organic "underload" type condition

b) Decreasing temperature decreases biological activity creating "organic overload" type conditions.

c) Control responses

1. If temperature increases:

a. Decrease the solids inventory.

b. Decrease solids aeration time.

2. If temperature decreases:

a. Increase the solids inventory.

b. Increase solids aeration time.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

3) Dissolved oxygen

   a) Preferred range: 1-3 mg/l in all parts of the aeration basin.

   b) Filamentous growth encouraged if:

      1. D.O. > 6 mg/l

      2. D.O. < 1 mg/l

   c) D.O. > 3 mg/l may cause overaeration and encourage nitrification.

   d) Maintain sufficient D.O. in aeration basin to keep final clarifier sludge aerobic, i.e., should have measurable D.O. in the return sludge.

   e) Control Responses

      1. Profile aeration basin for D.O. and maintain 1.0 mg/l in all parts of the basin.

      2. Check and maintain air distribution system to avoid dead spots.

      3. Reduce air supply rate of D.O. > 3 mg/l.

C. Operating to Prevent Bulking (5 minutes)

1. Consistent, regular, routine monitoring of the activated sludge system provides data which can give early warning of changing conditions which could lead to bulking problems.

Use Slide 179.2/11.12.47

Slide 179.2/11.12.47 is a word slide which reads:

LESSON OUTLINE

2. Operator must interpret and respond to process monitoring data to maintain process conditions which promote good sludge quality and avoid conditions which promote bulking sludge quality.

3. Because many different factors can contribute to process conditions which promote the growth of bulking sludges, the operator must monitor, interpret and respond to many indicators of process condition. Slide 179.2/11.12.47 lists the process control information which provides data and clues to potential problem conditions.

4. The key is interpretation of the data and implementation of the correct process control responses to maintain system balance.

5. But even the best operator in a good plant may not be able to avoid bulky sludge conditions all the time. Therefore, the operator must know what to do if bulking does occur.

6. Also, the troubleshooter will often see systems which have deteriorated until a severe bulking problem exists. The troubleshooter must know what to do to correct the problem.

D. Operating with a Bulky Sludge

1. Use Slide 179.2/11.12.48 to summarize that:

   a. Bulky sludges often produce excellent effluents if

   b. The operator can keep the sludge in the clarifier, but

   c. Any hydraulic load increase may

KEY POINTS & INSTRUCTOR GUIDE

"Avoiding Bulking

Monitor and Respond to Changes in:

- F/M
- Solids Inventory
- MCRT
- MLSS Settleability
- Microscopic Observation
- Respiration Rate
  - MLSS
  - Fed Sludge
- Influent Flow Rate"

Use Slide 179.2/11.12.48

Slide 179.2/11.12.48 is a word slide which reads:

"Operating With Bulky Sludges

- May Produce Excellent Effluent
- Problem: Keeping Sludge in the Clarifier
- Danger: Solids Washout"

LESSON OUTLINE

cause solids washout because the clarifier is being operated at the limits of its solids handling capacity.

2. If operating with a slowly settling (bulky) sludge, then

   a. Monitor sludge blanket closely and try to keep it in the lower 1/3 - 1/2 of the clarifier.

   b. Increase the monitoring frequency for all other parameters and respond to parameter changes as needed because the bulky sludge is very sensitive to any change in the system parameters. Monitor at least once per operating shift and preferable twice per operating shift.

   c. Reduce return sludge rate and operate with lowest return rate possible which keeps sludge blanket in bottom half of the clarifier.

      1) Reduce hydraulic load to the clarifier.

      2) Allow as much clarifier sludge detention time as possible to promote sludge concentration in the clarifier.

      3) Operate to maximize aeration basin hydraulic detention time.

   d. Reduce or stop wasting to increase the solids inventory

      1) Increase solids aeration time.

      2) Decrease F/M.

      3) Reduce clarifier underflow velocity.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.12.49

Slide 179.2/11.12.49 is a word slide which reads:

"Operating with Bulky Sludge

- Reduce Return Sludge Flow Rate
- Stop Wasting
- Maintain Sludge Blanket in Lower Half of Clarifier"

e. Convert to sludge reaeration mode of operation if possible.

  1) Increase solids aeration time.

  2) Increase solids inventory.

f. If sludge blanket begins to rise in the final clarifier and solids washout appears imminent, then increasing return rate may offer temporary relief.

  1) Moves sludge from the clarifier to the aeration basin.

  2) Effect is temporary and relief is temporary (a few hours)

  3) As soon as the sludge blanket is lowered enough to prevent solids washout, reduce the return sludge flow rate.

    a) Increasing return creates aeration basin conditions which will probably make the bulking problem get worse.

    b) The long term solution to cure the problem is to reduce return rate as much as possible.

g. Should wasting be increased to lower the final clarifier sludge blanket?

  1) Usually, No!

    a) Wasting decreases solids inventory, increases F/M increases final clarifier underflow velocity and

LESSON OUTLINE

dilutes the return sludge concentration.

b) Wasting tends to make the bulking problem worse instead of better.

2) On rare occasions, Yes.

a) Increased wasting may be advised if the diluted sludge settles and concentrates better than the undiluted sludge, i.e., part of the problem is too many solids in the system.

b) Use Slide 179.2/11.12.50 to summarize tests to determine whether increased wasting is advised.

c) Warn class of dangers of wasting when bulking occurs.

h. Use of Settling Aids

1) Use Slide 179.2/11.12.51 to list settling aids which have been used with bulky sludges.

2) Advise class to perform laboratory settling tests using the aid before attempting to use them in the full scale plant.

3) Warn about problems:

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.12.50

Slide 179.2/11.12.50 is a word slide which reads:

"Should Wasting Be Decreased to Control Bulking?

- Usually NO!!!
- Special Case
  - Run Settling Test Using MLSS Diluted With Final Effluent
    - 100% MLSS
    - 75% MLSS
    - 50% MLSS
  - Calculate and Plot SSC Values for Each Dilution
  - If Diluted Samples Concentrate As Well As or Better Than the Undiluted Sample, then Wasting May Be Advised"

Note to Instructor: Settling test procedures are presented as Unit 11, Lesson 5.

Use Slide 179.2/11.12.51

Slide 179.2/11.12.51 is a word slide which reads:

"Settling Aids

- Activated Carbon
- Clay
- Hydrated Lime
- Digested Sewage Solids
- Alum
- Ferric Salts
- Polymers"

a) Lime is caustic.

b) Alum may cause pH drop.

c) Ferric salts are corrosive.

d) Polymers would be most useful in deflocculation or dispersed growth problems and normally not effective with filamentous bulking (polymer action is a bridging effect between floc particles not unlike the effect of the filaments in the bulky sludge).

E. Operating to Cure Bulking

1. Key to curing bulking is close control of the system to maintain solids inventory and work out the problem.

2. Use Slide 179.2/11.12.52 to summarize control responses to cure bulking.

   a. Reduce return rate

      1) Normally operate to SSC$_{50}$

      2) With bulky sludges may have to operate to SSC$_{120}$ or greater.

      3) Reduce return to concentrate sludge in clarifier, increase MLSS inventory, increase aeration time. Aeration detention time increase causes sludge to "oxidize" more (become more stable), settle faster, concentrate better and reduce RR.

   b. Stop wasting to increase solids inventory

      Trying to increase solids inventory and reduce F/M for all reasons stated above.

Use Slide 179.2/11.12.52

Slide 179.2/11.12.52 is a word slide which reads:

"Process Control to Cure Bulking

- Reduce Return Rate
- Stop Wasting
- Increase Solids Inventory
- Use Sludge Reaeration
- Increase Aeration Basin D.O."

LESSON OUTLINE

c. Control return sludge closely

   1) Increase aeration basin detention time.

   2) Reaerate sludge if possible

   3) 1/3 - 3/4 aeration tank volume for reaeration

   4) Add digester supernate (Kraus modification) to reaeration basin.

      Note addition to reaeration tank. Otherwise, supernate may cause shock load and accentuate the problem.

d. Increase aeration basin D.O. to increase oxidation pressures.

3. Aids to Cure Bulking

   a. Note that aids treat symptoms, not causes.

   b. Add disinfectant.

      1) Chlorinate to destroy filaments. Potentially dangerous because you are adding disinfectant to living system and may over-kill.

      2) Chlorinate return

         a) 2-3 #Cl_2/1000 #MLSS

         b) 10-20 mg/l Cl_2

         c) 5-7 #Cl_2/1000 #MLSS can cause deflocculation

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.12.53

Slide 179.2/11.12.53 is a word slide which reads:

"Aids to Cure Bulking

- Add Disinfectant
  - Chlorinate Return
    - 2-3 #Cl_2/1000 #MLSS
    - 10-20 mg/l Cl_2
    - 5-7 #Cl_2/1000 #MLSS May Cause Deflocculation
  - Chlorinate Stale or Septic Sewage
  - Hydrogen Peroxide
- Feed Alum
  - 8-12 mg/l for 24 hours
  - Add Lime to Maintain pH in Range 6.2 - 6.6"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3) Chlorinate raw sewage Add 5-10 mg/l Cl_2 if sewage is stale or septic.	
4) Add hydrogen peroxide: a) 200 mg/l in return b) 24 hour period	Note: Hydrogen peroxide addition is more expensive than chlorination. Objectives with hydrogen peroxide and chlorine are similar
c. Feed alum to secondary clarifier influent 1) 8-12 mg/l for 24 hours 2) Corrosive 3) Excess alum can cause pH drop 4) Add lime to keep pH in range 6.2 - 6.6 5) Coagulant aid to weight sludge 6) Part of effect may be due to lowered pH for short period.	
VI. Discussion Use any remaining time for questions and answers.	Use Slide 179.2/11.12.54 Slide 179.2/11.12.54 is a blank

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 12: Sludge Settling Problems

Trainee Notebook Contents

Final Clarifier Settling Problems. T11.12.1

Estimating Final Clarifier Solids Handling Capacity T11.12.7

Figure T11.12.1 - Mixed Liquor Suspended Solids Settling Test Results Showing Tangent Line for Calculating Solids Settling Velocity T11.12.14

Figure T11.12.2 - Construction of Final Clarifier Total Solids Flux Curve. T11.12.15

Figure T11.12.3 - Interpretation of Solids Settling Flux Analysis T11.12.16

Final Clarifier Settling Problems

I. Types of Settling Problems

A. Floc Formation Problems

1. Normal Sludge

   a. Few short filaments.
   b. Protozoa present, mostly free-swimming ciliates and stalked ciliates.
   c. Nematodes, rotifers, crustaceans and insects may be present.
   d. Supernatant contains few individual bacterial cells.

2. Dispersed Growth

   a. Short bacterial filaments, yeast cells and flagellated protozoans.
   b. Non-flocculent with many individual cells in suspension.
   c. Considered to be something other than activated sludge.

3. Deflocculation

   a. May be caused by cessation of reaction with waste because of toxic or inhibitory substances.
   b. Due to bacterial die-off with floc particles actually breaking up.
   c. May be caused by excessively high or low pH.

4. Pin Floc

   a. Looks like fly ash which is relatively inert and has low BOD.
   b. Floc looks normal but it does not settle and has a high BOD.

5. Billowing Sludge

   a. Hydraulic factors in final clarifier.
   b. Poor design in secondary clarifiers.
   c. Poor final clarifier operation and maintenance.

SOURCE: Pipes, Wesley O., "Bulking of Activated Sludge," *Advances in Applied Microbiology*, 9, 185-234 (1967).

B. Density Problems

1. Rising Sludge

   a. Due to nitrification in the aeration tank and denitrification in the sedimentation tank.
   b. Nitrogen gas carries particles of sludge to the surface of the clarifier.

2. Anaerobic Sludge

   a. Gases produced in the absence of denitrification are CO_2, H_2 and H_2S causing sludge to float.
   b. Due to poor design or operation of the settling tank allowing sludge to compact for hours without removal.

3. Overaerated Sludge

   a. Aerated violently enough to cause small bubbles to attach to sludge and cause deflocculation or floating sludge.
   b. Presence of grease accentuates the problem.

4. Floating Sludge

   a. Usually quite filamentous.
   b. Many dead stalked ciliates.
   c. Rotifers and nematodes may be killed by predatory organisms.
   d. May have saprophitic fungii which have large diameter hyphae and vacuoles containing lipids causing them to float.

C. Compaction Problems

1. Zoogleal Bulking

   a. Due to nonfilamentous organisms containing excessive amounts of bound water.
   b. Microscopic investigation shows ragged and diffused sludge with relatively large surface area.
   c. May be closely related to one of the deflocculation phenomena.

2. Filamentous Bulking

   a. May produce SVI of greater than 200.
   b. Supernatant very clear but very little supernate is processed.

c. Sludge particles appear normal except filaments extend from clumps and are much more numerous and much longer.

d. Filamentous organisms predominate because process conditions favor their growth.

II. Superficial Aspects of Bulking

A. Plant Operation

1. Operating with filamentous bulking (Produces a good effluent if sludge can be kept in the clarifier).

B. Suggested remedies for controlling activated sludge with filamentous bulking

1. May increase return sludge rate for temporary relief (lower high sludge blanket).

2. May increase waste sludge rate (this is not really recommended and seldom solves the problem) to lower the sludge blanket.

3. Correct response is to reduce return rate and reduce wasting rate to increase solids inventory and increase solids aeration time.

4. Add inert materials to increase the weight of the sludge.

   a. Activated carbon
   b. Clay
   c. Hydrated lime
   d. Digested sewage solids
   e. Raw sewage solids
   f. Alum
   g. Ferric salts
   h. Synthetic polymers

C. Operating to prevent filamentous bulking

1. Maintain proper solids inventory

2. Based on correct F/M ratio (.2 to .5)

3. Increase solids inventory if loading increases

4. Control of sludge return

a. Holding sludge in clarifier too long may tend to produce bulking because of anoxic conditions.
b. Reaerate return sludge before it is mixed with waste
c. Use between 1/3 to 3/4 the aeration capacity for reaeration.
d. Add digester supernatant to reaeration tank (Kraus modification). Digester supernatnat in conventional activated sludge may cause upset but appears to improve settling characteristics when used in sludge reaeration.

D. Waste Composition

1. Organic Content

a. High concentrations of carbohydrates produce bulking.
b. Simple soluble organic compounds which are readily metabolized by majority of microorganisms favor the growth of filamentous organisms.
c. More complex insoluble compounds which have to be hydrolized favor the growth of good settling sludge.
d. Stale or septic sewage is considered to be more likely to produce filamentous bulking than fresh sewage.
e. Sulphides may promote bulking.
f. More problems are found in periods of low flow in hot weather than when the weather is cool and flow has increased.

2. Inorganic Content

a. Inadequate amounts of nitrogen and phosphorous may lead to bulking.
b. There is some evidence of bulking when the carbon to nitrogen ratio is greater than 10.
c. Phosphorous concentrations less than 2 mg/l have been identified with filamentous sludge production.

3. Toxic Compounds

a. Continuous toxic contributions may prevent the formation of activated sludge.
b. It may selectively be toxic to filamentous organisms promoting a low SVI sludge.
c. It may be toxic to normal sludge organisms but not filamentous organisms.
d. Some toxic compounds if fed continuously can develop a good activated sludge. Examples of theses are phenols and cyanides.

e. A number of heavy metals are toxic to all organisms at high concentrations and definitely interfere with the activated sludge process.
f. Low concentrations of chromium may cause normal activated sludge to become filamentous.
g. Low concentrations of copper, nickel, zinc or chrome may prevent the formation of filamentous organisms.
h. Chlorine has been used in various ways to control filaments and the results range from good to poor. Results may be: both filaments and SVI are reduced; SVI may not be reduced but filaments may be lessened in the return sludge; chlorine may have no effect on filamentous bulking but may reduce the SVI in case of zoogleal bulking.

4. Shock Loading

a. Hydraulic overload may produce bulking by reducing the amount of solids in the system to the point that organic overloading takes place.
b. Toxic shock loads may produce bulking characteristics due to deflocculation rather than actual filamentous bulking.

E. Aeration Tank Environment

1. pH

a. Process normally operates fairly well between pH 6 and pH 9.
b. pH above 9 does not occur very frequently because CO_2 is produced which effectively lowers the pH.
c. pH's less than 5 generally produce deflocculation.
d. Extended periods of low pH will produce sludge composed of almost entirely filamentous organisms.

2. Temperature

a. Filamentous bulking is more liable to occur at high temperatures than low temperatures.
b. A higher solids inventory must be maintained at lower temperatures to prevent organic overloading.

3. Dissolved Oxygen

a. There is some confusion among the experts on an optimum level of DO and its relationship to filamentous bulking.

However, a level of 1 mg/1 DO in a mixed liquor appears to be the most commonly reported level when the plant is operating well.

b. The goal should be to maintain enough dissolved oxygen going into the secondary clarifier that the return sludge does not go septic while in the clarifier.

Estimating Final Clarifier Solids Handling Capacity

A frequently occurring problem in activated sludge treatment plants is inadequate solids handling capacity in the final clarifiers. The concept of solids flux can be used to evaluate the adequacy of final clarifier solids handling capacity.

Final Clarifier Solids Removal Mechanisms

1. Solids Settling

   Solids move relative to the liquid phase in the final clarifier because the more dense solids fall through the liquid.

2. Bulk Transport of Solids

   Solids are carried downward and out of the final clarifier in the hydraulic underflow (the return plus waste activated sludge flows) from the clarifier. This is purely an hydraulic transport effect.

3. Total Solids Movement

   The total rate of downward solids movement in the final clarifier is the sum of the movement caused by bulk transport (hydraulic underflow) plus the movement caused by the solids settling relative to the moving liquid.

Definition of Solids Flux

1. "Flux" is defined as the quantity of material passing through a unit area in a unit time. Typical units of "flux" are pounds/square foot/hour. "Flux" is the product of velocity times concentration.

2. Final Clarifier Bulk Transport Solids Flux.

   The final clarifier bulk transport solids flux is defined as the product of the final clarifier hydraulic underflow velocity (ft/hr) times the underflow solids concentration (lbs/ft^3).

a. Final Clarifier Hydraulic Underflow Velocity (ft/hr) =

$$\frac{\text{Final Clarifier Underflow Rate } (ft^3/hr)}{\text{Final Clarifier Surface Area } (ft^2)}$$

b. Final Clarifier Bulk Transport Solids Flux (lbs/ft^2/hr) =

Final Clarifier Hydrualic Underflow Velocity (ft/hr) X
Underflow Solids Concentration (lbs/ft^3)

3. Final Clarifier Solids Settling Flux

The final clarifier solids settling flux is defined as the product of the solids settling velocity (ft/hr) times the solids concentration (lbs/ft^3).

a. Solids Settling Velocity

The solids settling velocity is estimated using laboratory settling test data. The following describes the procedure for estimating solids settling velocity using settling test data:

1) Perform a mixed liquor suspended solids settling test using a settleometer or 1000 ml graduated cylinder. Record the SSV values at 10 minute intervals as a function of settling time for at least one hour (see limitations).

2) Measure and record the mixed liquor total suspended solids concentration as gms/l. Calculate the SSC (gm/l) values as a function of the time using the formula:

$$SSC_t = \frac{\text{MLSS (gm/l) X 1000}}{SSV_t \text{ (ml)}}$$

3) Plot the SSV values as a function of time. Determine the linear depth in feet equivalent to each SSV value for your settling test vessel. For example, SSV = 1000 in a commercial settleometer is equivalent to 0.50 ft depth; SSV = 500 in a commercial settleometer is equivalent to 0.25 ft. depth; and SSV = 0 is equivalent to 0.00 ft depth. Superimpose the depth scale over the SSV scale on the ordinate (y - axis) of the SSV vs time plot. The plot now depicts settleometer sludge blanket thickness as a function of time. (see figure T 11.12.1, page T 11.12.14).

4) Estimate the settling velocity of the settleometer sludge blanket interface by determining the slope of the tangent to the settleometer sludge blanket depth vs. time curve for several settling times. A minimum of seven tangents (settling velocities) corresponding to 0, 10, 20, 30, 40, 50, and 60 minute settling times should be calculated. Convert the settling velocities to units of ft/hr. (See Figure T11.12.1, page T11.12.14).

b. Calcualte solids settling flux as a function of SSC

1) From the SSC vs. time plot, determine the solids concentration corresponding to each settling time for which a settling velocity is calculated.

2) Calculate the solids settling flux for each settling time using the formula:

Solids Settling Flux ($lbs/ft^2/hr$) = Solids settling velocity (ft/hr) x solids concentration (gm/l) x 0.06243 [(lbs/ft^3)/(gm/l)]

Estimating Final Clarifier Total Solids Flux

1. Determine the final clarifier hydraulic underflow velocity in ft/hr.

2. For the given final clarifier hydraulic underflow velocity, calculate the final clarifier bulk transport solids flux for several SSC values.

3. Prepare the following solids flux plot as a function of SSC. Plot solids flux ($lbs/ft^2/hr$) as the ordinate and SSC (lbs/ft^3) as the abscissa. Plot two curves on the same set of axis:

   a. Solids settling flux

   b. Final Clarifier Bulk Transport solids flux (see Figure T11.12.2, page T11.12.15).

4. Determine the total final clarifier solids flux at a given SSC as the sum of the solids settling flux plus the final clarifier bulk transport solids flux.

5. Plot the total final clarifier solids flux as a function of SSC (see Figure T11.12.3, page T11.12.16).

6. The minimum in the final clarifier total solids flux vs. SSC curve is the solids handling capacity of that clarifier operating at the given underflow velocity which is fed mixed liquor suspended solids having the settling characteristics observed in the laboratory settling test (see Figure T11.12.3, page T11.12.16).

Interpretation of Findings

1. The minimum in the final clarifier total solids flux curve represents the maximum final clarifier solids handling capacity for the operating conditions of underflow velocity and solids settling characteristics as determined above.
    a. If the solids feed to the clarifier is greater than the final clarifier solids handling capacity, the sludge blanket will rise.
    b. If the solids feed to the clarifier is less than the final clarifier solids handling capacity, the sludge blanket will fall.
2. Increasing the solids settling velocity will increase the solids handling capacity of the final clarifier. Decreasing the solids settling velocity will lower the solids handling capacity of the final clarifier.
    a. Changes in solids inventory, aeration basin loading, MCRT, F/M, aeration basin hydraulic detention time, solids aeration time, return sludge flow rate, waste sludge rate, temperature, etc. will cause solids settling characteristics to change as discussed in previous lessons.
    b. Therefore, final clarifier solids handling capacity is not a constant. It changes with operating conditions. The operator's role is to know the constraints on final clarifier solids handling capacity and make correct operational responses to avoid final clarifier solids handling limitations consistent with overall system process control objectives.
3. Increasing final clarifier hydraulic underflow velocity increases final clarifier solids handling capacity if solids settling characteristics do not change.
    a. Increasing final clarifier underflow velocity moves solids through the clarifier faster but dilutes the underflow solids concentration.

   b. Increasing final clarifier underflow velocity creates process conditions which tend to cause the solids settling velocity to decrease.

   c. Increasing final clarifier hydraulic underflow velocity increases hydraulic load on the clarifier affecting both clarification and thickening characteristics of the final clarifier.

4. Decreasing final clarifier hydraulic underflow velocity decreases final clarifier solids handling capacity if solids settling characteristics do not change.

   a. Decreasing final clarifier underflow velocity reduces the rate at which solids move through the clarifier but yields a more concentrated underflow solids concentration.

   b. Decreasing final clarifier underflow velocity creates process conditions which tend to cause the solids settling velocity to increase.

   c. Decreasing final clarifier hydraulic underflow velocity decreases the hydraulic load on the clarifier affecting both clarification and thickening characteristics of the final clarifier.

5. The final clarifier solids underflow concentration can be estimated by drawing a horizontal line tangent to the minimum point on the final clarifier total solids flux vs. SSC curve. The horizontal tangent line and the bulk transport solids flux line intersect at a SSC value corresponding to the expected final clarifier underflow solids concentration.

   a. The underflow concentration will be higher than the SSC value corresponding to the limiting total solids flux because solids cannot settle through the bottom of the final clarifier. All solids must be removed from the final clarifier by bulk transport alone.

   b. This procedure can be used to estimate the effect of a change in final clarifier underflow velocity on the underflow solids concentration.

Limitations

1. Laboratory settling conditions are not the same as final clarifier settling conditions. It is reported that the procedures described give conservative results.

2. Solids settling velocity is a function of the height of the settling column used in the laboratory test procedure. Best and most dependable results are obtained by using a 6-8 foot settling column.

Example Analysis of Final Clarifier Solids Handling Capacity

1. Settling Test Results

Sludge Settling Time (SST), min	Settled Sludge Volume (SSV), ml	Settled Sludge Concentration (SSC), gm/l	Settled Sludge Concentration (SSC), lb/ft^3	Blanket Thickness, ft
0	1000	3.0	0.187	1.00
10	380	7.89	0.493	0.38
20	277	10.83	0.676	0.28
30	230	13.04	0.814	0.23
40	210	14.29	0.892	0.21
50	204	14.71	0.918	0.20
60	200	15.00	0.936	0.20

(1.0 gm/l = 0.06243 lb/ft^3)

2. Plot SSV and SSC vs. SST, Figure T11.12.1.

3. Calculate solids settling velocity

   a. Draw tangent lines to SSV vs. SST curve as shown in Figure T11.12.1.

   b. Calculate solids settling velocity at various SST.

4. Calculate solids settling flux for various SST.

SST minutes	Solids Settling Velocity ft/hr	Solids Settling Flux lbs/ft^2/hr
0	20.0	3.740
10	1.02	0.503
20	0.41	0.277
30	0.16	0.130
40	0.05	0.045
50	0.03	0.028
60	0.03	0.028

5. Plot solids settling flux vs. SSC as shown in Figure T11.12.2.

6. Assume that the final clarifier has 2000 ft^2 surface area and that the underflow rate (return plus waste activated sludge flow rate) is 400,000 gpd. Then the underflow velocity is 1.114 ft/hr.

7. Calculate the final clarifier bulk transport solids flux and plot as shown in Figure T11.12.2.

8. Construct total solids flux curve as shown in Figure T11.12.2.

9. Identify limiting final clarifier solids flux as minimum point on total solids flux curve as shown in Figure T11.12.3. In this example, the limiting final clarifier solids flux is 0.86 lb/ft^2/hr or 20.6 lb/ft^2/day.

10. Estimate final clarifier underflow solids concentration as shown in Figure T11.12.3. In this example the final clarifier underflow solids concentration is 0.955 lbs/ft^3 or 15.3 gm/l (15,300 mg/l).

11. The solids handling capacity of the final clarifier in this example is 41,200 lbs/day. This is the product of the final clarifier surface area times the limiting final clarifier solids flux.

T11.12.14

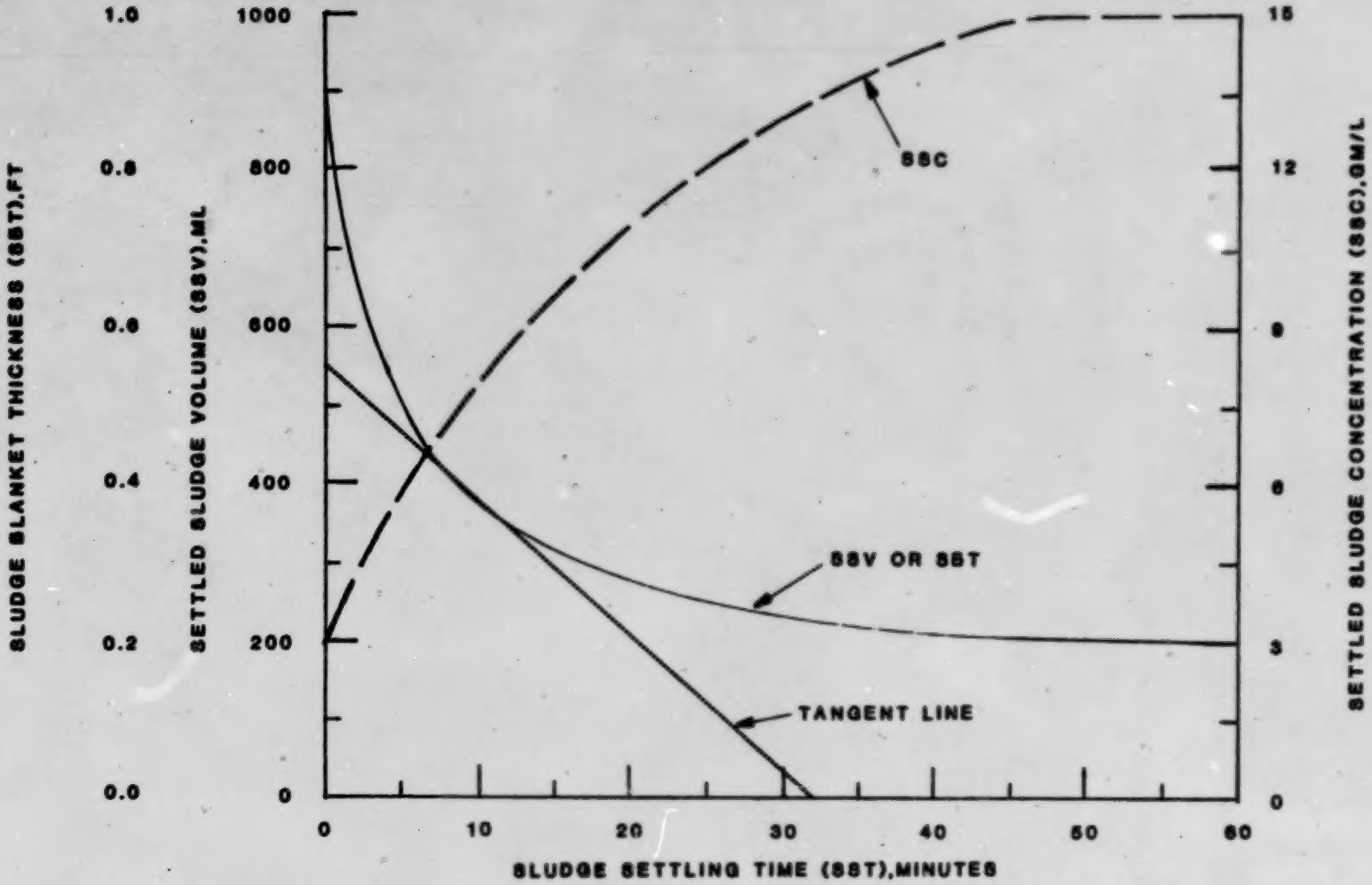


FIGURE T 11.12.1. MIXED LIQUOR SUSPENDED SOLIDS SETTLING TEST RESULTS SHOWING TANGENT LINE FOR CALCULATING SOLIDS SETTLING VELOCITY

T11.12.15

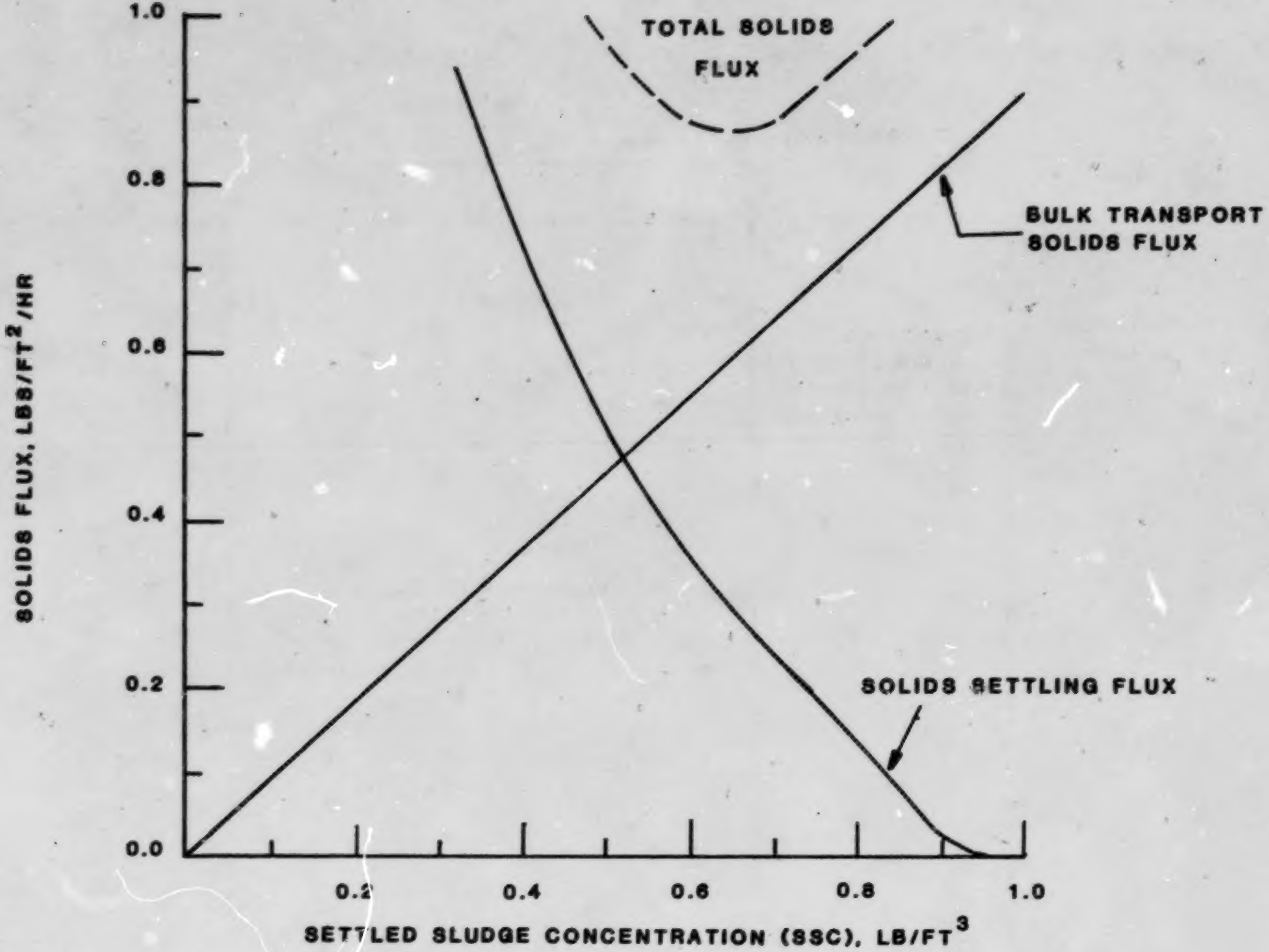


FIGURE T 11.12.2. CONSTRUCTION OF FINAL CLARIFIER TOTAL SOLIDS FLUX CURVE

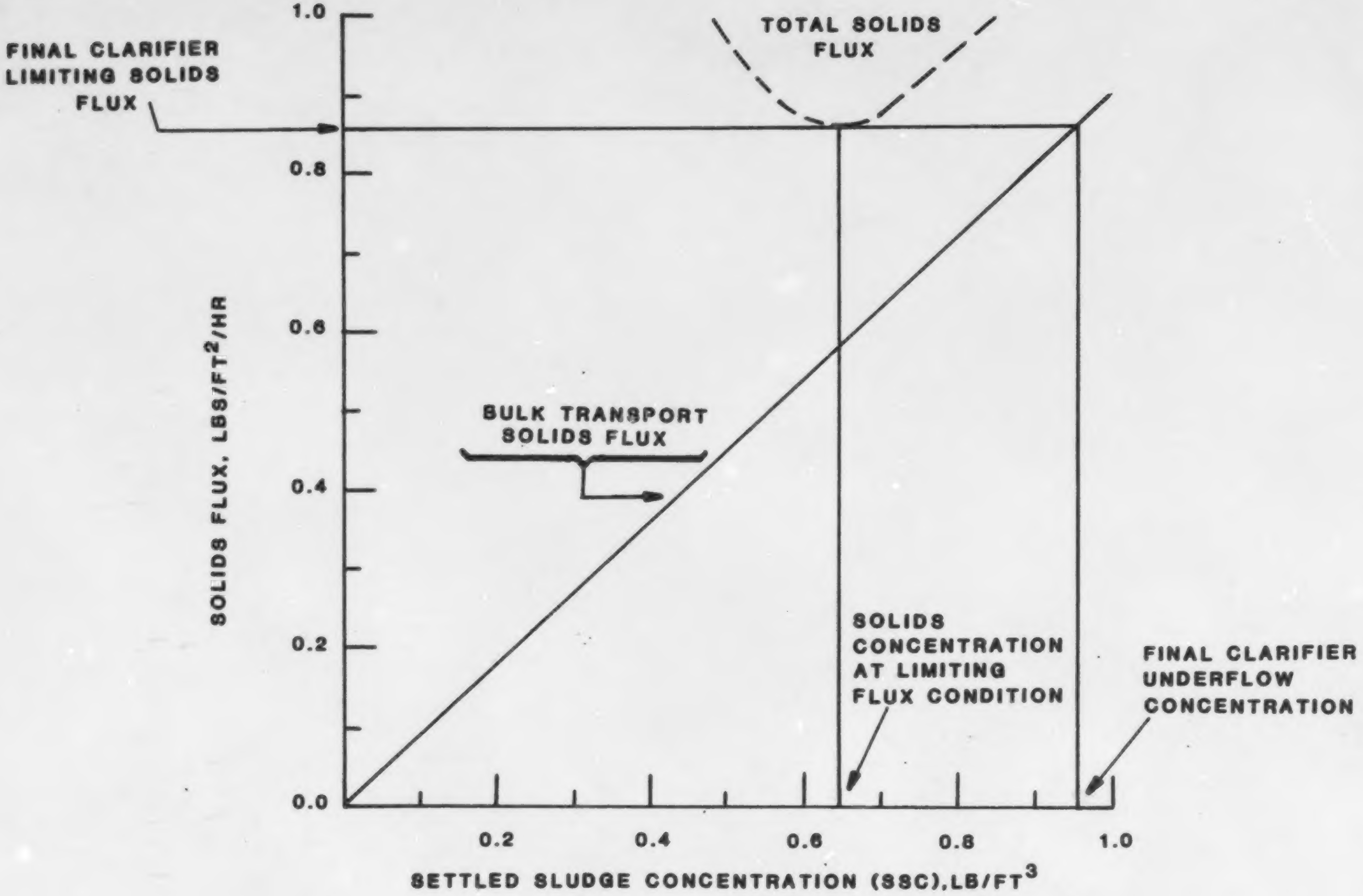


FIGURE T 11.12.3. INTERPRETATION OF SOLIDS SETTLING FLUX ANALYSIS

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 13: Mini-Case Histories

Lesson 13 of 14 lessons Recommended Time: 50 minutes

Purpose: This lesson provides the trainee experience in analyzing non-process related problems which occur in activated sludge plants. The lesson presents six short case histories with solutions for various mechanical and hydraulics problems which occur in activated sludge facilities.

Trainee Entry Level Behavior: The trainee should have achieved the learning objectives for Unit 11, Lessons 1 - 12 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. Recognize and recommend solutions to the following problems in activated sludge treatment plants:
    a. Hydraulic surging caused by improperly operated and controlled raw sewage pumps.
    b. Flow imbalance caused by unequal discharges from multiple gravity flow entry ports to rectangular aeration basins and final clarifiers.
    c. Hydraulic short circuiting in final clarifiers caused by excessive weir length and improper weir placement in final clarifiers.
    d. Return sludge flow control in small plants achieved by using portable pumps.
    e. Inadequate mixing in aeration basins caused by poorly designed surface mechanical aerator draft tubes.
    f. Final clarifier flow imbalance caused by a blocked inlet or outlet structure.
2. Explain the importance of good pre-startup inspection and cite at least two examples showing how problems could have been prevented by adequate start-up and construction inspections.

Instructional Approach: Illustrated lecture with trainee problem solving and discussion.

Lesson Schedule: The 50 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 5 minutes	Flow Surging
5 - 15 minutes	Flow Imbalance
15 - 20 minutes	Hydraulic Imbalance
20 - 25 minutes	Return Sludge Flow Control in Small Plants
25 - 35 minutes	Inadequate Mixing
35 - 40 minutes	Blocked Clarifier Inlet
40 - 50 minutes	Discussion

Trainee Materials Used in Lesson:

1. Paper and pen for note taking.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 11.13.1-11.13.11, Unit 11, Lesson 13.
2. Slides 179.2/11.13.1 - 179.2/11.13.28.

Instructor Materials Recommended for Development: None

Additional Instructor References: None

Classroom Set-Up: As specified in Unit 11, Lesson 1.

LESSON OUTLINE

I. Case History - Hydraulic Surging (5 minutes)

A. Plant Background

1. Slide shows 24 hour influent flow

2. 10 MGD activated sludge plant

3. Raw sewage pumps are turned on and off manually.

There are three pumps in the raw sewage lift stations. Two are fixed speed pumps rated at 6 MGD. The other is variable speed with a maximum capacity of 6 MGD. The lift operators must drive to the station to turn on the pumps when they are needed. Night staffing at the plant is minimal and the night operators do not go to the lift station to turn on the pumps or to control discharge rates from the variable speed pump.

B. Plant Problem

This chart shows that there is a 7.5 MGD step in the influent flow rate each morning when the day shift activates the pumps. The second blip on the chart is caused by the variable speed pump being turned to a higher discharge rate. The step increase in influent flow causes hydraulic washout of the solids in the final clarifiers. As a result of the influent flow schedule, which is regular as clockwork day after day, the plant is operated to store solids in the aeration basins during the low flow periods so that added load of the step can

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.13.1
Slide 179.2/11.13.1 is a blank

Use Slide 179.2/11.13.2
Slide 179.2/11.13.2 is a photograph of a circular flow chart recording which shows a 7.5 MGD increase in flow rate as a step load to the facility.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
be handled by the sludge. This practice contributes to the hydraulic washout problem as solids are moved from the aeration basin to the final clarifiers.	
C. Class Analysis of Problem	Guide: Instructor should encourage class discussion of the problem.
D. Actual Solution of Problem In the plant from which this case history is taken, the lift station is equipped with an automated flow controller, but it was never connected to the pumps and put into service.	Guide: Instructor should present what really happened after the class has had an opportunity to discuss the problem.
E. Plant Improvement 1. Slide shows the influent flow chart two days later after the automatic controller was placed in service. The flow smoothing which occurs eliminated the hydraulic washout of the final clarifiers. This required that the operators learn a new way to operate the process since the old mode of operation was no longer needed. Eventually the activated sludge process was balanced and overall plant efficiency increased appreciably.	Use Slide 179.2/11.13.3 Slide 179.2/11.13.3 is a photograph of a flow chart at the same facility showing the gradual increase in load when properly installed flow matcher system was used.
2. This slide permits a more ready comparison of the influent flow patterns before and after the automatic controller was placed in service.	Use Slide 179.2/11.13.4 Slide 179.2/11.13.4 is a photograph of the two flow charts shown in the previous slide which permits comparison of the flow smoothing achieved by proper control of raw sewage pumps.
II. Case History - Flow Imbalance (10 minutes) A. Plant Problem Slide shows obvious unequal flow from the two ports. Point out that there are other	Use Slide 179.2/11.13.5 Slide 179.2/11.13.5 is a photograph showing two rectangular inlets to an aeration basin. The inlet on the left has an obviously greater flow than the inlet on the right.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
basins to the left which also have similar problems since all ports feed from the same channel. Point out that each port is fitted for a slide gate to block flow from that port.	
B. Class Analysis of Problem	Guide: Instructor should ask the students for recommendations on balancing flow thru the basins.
C. Actual Solution of the Problem 1. When the discharge ports are submerged with a six to eight inch discharge head, the flow could be balanced. Slide shows the installation of stainless steel machine bolts into the bottom side of the discharge port gate. The bolts were purchased at the local hardware store and a local machine shop tapped the gate for the bolts. The operator is shown here adjusting the height of one bolt using a micrometer gauge.	Use Slide 179.2/11.13.6 Slide 179.2/11.13.6 is a photograph showing an operator installing machine bolts on the end of the weir plate.
2. Slide shows the gate being inserted into the port.	Use Slide 179.2/11.13.7 Slide 179.2/11.13.7 is a photograph showing the operator inserting the weir plate into the channel opening.
3. Slide shows the balanced flow after all the gates had been adjusted to the correct heights.	Use Slide 179.2/11.13.8 Slide 179.2/11.13.8 is a photograph showing the inlet ports to the aeration basin with equal flows from the submerged weir inlets installed to balance flows.
4. Slide shows the entire plant looking from the effluent side of the final clarifier toward the aeration basins. Point out the gates installed at the head of the aeration basin to balance flow and the similar gates installed at the inlets to the final clarifier.	Use Slide 179.2/11.13.9 Slide 179.2/11.13.9 is a photograph of the treatment facility shown in the previous slides showing the final clarifiers and aeration basins.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
5. Slide shows a closeup of the final clarifier ports with the gates in place. Point out the obvious velocity current as the mixed liquor enters the final clarifier. Inform the class that later the clarifiers were dewatered and target plates installed to correct this problem.	Use Slide 179.2/11.13.10 Slide 179.2/11.13.10 is a photograph of the final clarifier shown in Slide 179.2/11.13.9 which shows a sludge plume at the inlet to the clarifier.
III. Case History - Hydraulic Imbalance (5 minutes)	
A. Plant Problem Point out the excessive weir length in the corners of the basin caused by the inclusion of both corner and diagonal weirs.	Use Slide 179.2/11.13.11 Slide 179.2/11.13.11 is a schematic diagram of a rectangular final clarifier with extra weir space in the corners. The schematic includes arrows indicating high velocities in the direction of the corner weir plates.
B. Class Analysis of Problem 1. Confirm that the extra weir length in the corners does indeed cause a direct short-circuiting and excessive flow to the corners washing solids over the weirs at the corners. 2. Point out the simple correction shown in the lower left hand corner. Block off the weirs that are causing the problem.	Guide: Ask the class what they think would happen in this clarifier.
C. Effect of Weir Problem Slide shows billowing sludge in the anular space between the outermost weir and the wall of the clarifier. Note to the class that sludge quality is good and that the sludge settles well.	Use Slide 179.2/11.13.12 Slide 179.2/11.13.12 is a photograph of a final clarifier weir structure showing billowing sludge near the wall.
D. Actual Solution of the Problem Slide shows that the problem was solved by blocking off both the outermost and outer	Use Slide 179.2/11.13.13 Slide 179.2/11.13.13 is a photograph of the same final clarifier weir structure after excess weirs near

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
anular weir to eliminate the hydraulic washout of sludge caused by the velocity currents at the wall.	the wall had been locked to prevent solids carry-over.
IV. Case History - Return Sludge Flow Control at Small Plants (5 minutes)	Note: This problem is optional
A. Plant Problem	Use Slide 179.2/11.13.14 Slide 179.2/11.13.14 is a photograph of an operator removing the housing from the return sludge pump.
The operator of this plant was asked to modify the return sludge flow rate, stated that he could only change it about 15% and didn't want to do so because it would be difficult. When asked to show how he changed return flow rate, he demonstrated the following:	
1. He went to the shop and got most of his tool chest.	
2. He went to the return sludge pump and removed the pump housing.	
3. Loosened the impeller shaft retaining nut.	Use Slide 179.2/11.13.15 Slide 179.2/11.13.15 is a photograph of an operator using the sledge hammer to lower the shaft in the return sludge pump.
4. Took his hammer and banged down the pump impeller shaft.	
5. Went to the control panel to check to see if the flow was correct.	
6. Repeated 4 and 5 until the correct flow was obtained.	
7. Reassembled the pump and waited for the next requirement to change return flow.	
Any question why this operator didn't adjust return flow to satisfy process demands? Note that this is a small plant with flows of about 0.5 MGD.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
B. Class Analysis	Guide: Have class discuss, then recommend solutions to this problem.
C. Actual Solution of Problem Because the plant is small, portable pumps can be used as an interim measure while the uncontrollable return pump is being replaced.	Use Slide 179.2/11.13.16 Slide 179.2/11.13.16 is a photograph showing portable pumps being used to provide capability to control return sludge flows.
V. Case History - Inadequate Mixing (10 minutes)	
A. Plant Problem	Use Slide 179.2/11.13.17
1. Show slide pointing out the dead spots between aerators. State that in the plant the MLSS was very low and the plant was never able to develop sludge.	Slide 179.2/11.13.17 is a photograph of an aeration basin containing two surface mechanical aerators. The basin is covered with a crisp, white foam and there is evidence of stagnant areas in the basin.
2. The bottle on the left is a settled sample of the mixed liquor taken from the surface of aerator Bay No. 1. The bottle on the right is a sample taken from the bottom of the aerator Bay No. 1. The bottom sludge was 40,000 mg/l and 1,500 mg/l in the surface sample.	Use Slide 179.2/11.13.18 Slide 179.2/11.13.18 is a photograph of two BOD bottles containing mixed liquor samples drawn from top and the bottom of the aeration basin shown in Slide 179.2/11.13.17. The MLSS sample taken from the surface of the tank has very few solids compared with the sample taken near the bottom of the tank.
B. Class Analysis	Guide: Ask the class to identify the problem and its probable cause.
C. Actual Problem and Causes The problem is inadequate mixing in the aeration basin which permits the solids to settle out in the aeration basins rather than being held in suspension. Possible causes include undersized mechanical aerators, too few mechanical aerators, inadequate draft tubes on the mechanical aerators, etc.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
D. Attempted Troubleshooting of Problem	
1. This slide shows one of the aerators being lifted from the tank.	Use Slide 179.2/11.13.19 Slide 179.2/11.13.19 is a photograph showing the operator removing a surface mechanical aerator from the aeration basin.
2. Slide shows the draft tube on the aerator. Note that this is about an 18 inch draft tube on an aerator in a 20 foot deep aeration tank. Anyone question why mixing was inadequate?	Use Slide 179.2/11.13.20 Slide 179.2/11.13.20 is a photograph of the surface mechanical aerator showing that it has only about a 12 - 18" draft tube.
3. Slide shows the operators replacing the draft tubes with an eight foot draft tube set which was at the plant site. Note that the construction grant on this project had not been closed out and corrections were still being made.	Use Slide 179.2/11.13.21 Slide 179.2/11.13.21 is a photograph showing the operators installing an 8 foot draft tube on the surface mechanical aerator.
4. Slide shows the aerator with the longer draft tube being returned to service.	Use Slide 179.2/11.13.22 Slide 179.2/11.13.22 is a photograph showing the surface mechanical aerator with the 10 foot draft tube being lowered into the aeration basin.
5. Slide shows the black septic sludge from the tank bottom being disturbed as the new aerator was first put into service. But alas, the problem still persists because the draft tubes don't reach far enough into the tank as shown on the next slide. Within a few hours things had settled out again and no noticeable improvement was achieved.	Use Slide 179.2/11.13.23 Slide 179.2/11.13.23 is a photograph showing the aeration basin after the aerator with extended tubes is put into service. The contents of the aeration appear very black and septic. Use Slide 179.2/11.13.24 Slide 179.2/11.13.24 is a photograph taken approximately 30 minutes after Slide 179.2/11.13.23. The later photograph shows the aeration basin again experiencing problems of inadequate mixing and stagnant areas.

LESSON OUTLINE

E. Epilogue - Ode to the Troubleshooter!

The troubleshooter in this case called this problem to the attention of the City Engineer forcefully. He in turn has demanded that the consulting engineer and aerator manufacturer correct the inadequacy. Ah! The beauty of catching problems early.

VI. Case History - Blocked Clarifier Inlet (5 minutes)

A. Plant Background

A plant had been in operation for more than eight years and had always been plagued with unequal flows to the two final clarifiers.

B. Class Analysis of the Problem

Some of the causes which might be identified include:

1. Overflow weirs out of level.
2. Improper hydraulics in inlet channels.
3. Line blockages on inlet side of the clarifiers.

C. Troubleshooting the Problem

The obvious causes were checked immediately. It was determined that the effluent weirs were level and at the same elevation. Inlet channel hydraulics were checked out and no discernible problems were found. The troubleshooter recommended that the clarifier receiving low flow be dewatered and thoroughly inspected. This was done as shown in the slide. During the inspection a 4 x 8 foot piece of plywood which the contractor had left in the inlet structure of the clarifier was found.

KEY POINTS & INSTRUCTOR GUIDE

Key Point: Quick troubleshooting assistance can be invaluable.

Guide: Ask class to identify possible causes of the flow imbalance.

Use Slide 179.2/11.13.25

Slide 179.2/11.13.25 is a photograph of an empty rectangular final clarifier showing the inlet and sludge collection mechanisms.

LESSON OUTLINE

D. Epilogue

It's hard to believe that his problem had persisted for eight years and that no one had found the cause. A good, pre-start inspection and a thorough, planned start-up procedure should have surfaced this problem and solved it long before the troubleshooter was ever called in.

VII. Other Case History Problems (10 minutes)

A. Ask the class to identify any other problems that they have seen and would like to present to the class for discussion.

B. If time is remaining, the instructor may introduce any case history problems with which he/she is familiar that may be of interest to the class.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.13.26

Slide 179.2/11.13.26 is a photograph showing two operators removing a 4 x 8 sheet of plywood from the clarifier inlet structure.

Use Slide 179.2/11.13.27

Slide 179.2/11.13.27 is a photograph of the plywood sheet removed from the final clarifier inlet.

Use Slide 179.2/11.13.28

Slide 179.2/11.13.28 is a blank

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 14: Unit Summary

Lesson 14 of 14 lessons   Recommended Time: 50 minutes

Purpose: The Unit of Instruction on activated sludge process troubleshooting includes fourteen lessons. This lesson summarizes the key points in the activated sludge unit of instruction and provides an opportunity for trainees to clarify the information presented in the unit through questions, answers and discussion.

Trainee Entry Level Behavior: The trainee should have achieved the learning objectives specified for Unit 11, lessons 1 - 13 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. Using references and class notes, summarize the principal points presented in the activated sludge unit of instruction.
2. Seek clarification or further explanation on any aspect of activated sludge process troubleshooting and process control by posing questions to the instructor and to other trainees.

Instructional Approach: Illustrated lecture followed by a question, answer and discussion period.

Lesson Schedule: The 50 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 25 minutes	Instructor Summarizes the Unit of Instruction on Activated Sludge Process Troubleshooting
25 - 50 minutes	Questions and Discussion

Trainee Materials Used in Lesson:

1. All *Trainee Notebook* materials and handouts for Unit of Instruction 11 should be available for trainee reference. No specific review or summary materials for lesson 14 are included in the *Trainee Notebook*.

2. *Trainee Notebook*, pages T11.14.1 - T11.14.3, "Activated Sludge Process Control Troubleshooting References."

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 11.14.1 - 11.14.21, Unit 11, Lesson 14.

2. Slides 179.2/11.14.1 - 179.2/11.14.7.

Instructor Materials Recommended for Development: None

Additional Instructor References: *Instructor Notebook*, Unit 11, Lessons 1-13, pages 11.1.1 - 11.13.11.

Classroom Set-up: As specified in Unit 11, Lesson 1.

LESSON OUTLINE

I. Activated Sludge Unit Summary (25 minutes)

A. Note that Activated Sludge Process Troubleshooting was presented as the 13 preceding lessons totalling 13 hours of instruction. The 14th lesson in activated sludge process troubleshooting is to summarize, review and discuss the principal points covered in the preceding lessons in the unit of instruction.

B. Sludge Quality

1. Most activated sludge process control problems relate to an inability to separate solids in the final clarifier.
2. Activated sludge process objective is to convert non-settleable biodegradable organics to settleable solids and remove the settled solids from the system.
3. Process objective can be achieved if good sludge quality is maintained.
4. Use Slide 179.2/11.14.2 to compare and contrast good and bad sludge quality.
5. If good sludge quality is maintained then the final effluent will usually be low in both BOD and TSS.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.14.1
Slide 179.2/11.14.1 is a blank

Note to Instructor: The instructor should be thoroughly familiar with all materials presented in the activated sludge unit of instruction. If several instructors presented the activated sludge lessons, all instructors should be present during the summary lesson and assembled as a response panel to answer trainee questions. One instructor should serve as a moderator for the response panel. The moderator should present the summary materials.

Use Slide 179.2/11.14.2
Slide 179.2/11.14.2 is a word slide which reads:

"Sludge Quality

Good
- Settles fairly rapidly
- Concentrates uniformly in 30 - 60 minutes
- Flocculent
- Clear Supernate
- Deep Tan or Light Brown

Bad
- Settles Very Fast or Very Slowly
- Concentrates Very Quickly (<30 minutes) or Very Slowly (2-4 hours)
- Granular or Excessively Fluffy
- Cloudy, Turbid, Straggler Floc, Pin Floc or Ashing
- Light Tan, Very Dark Brown or Black"

LESSON OUTLINE

C. Factors Affecting Sludge Quality

1. Waste characteristics

    a. Quantity of biodegradable organics applied.

        1) May be measured as BOD, COD, TOC, TOD, etc.

        2) Usually normalized and expressed as:

            a) F/M, quantity of organics applied per unit of activated sludge solids per unit time.

            b) Loading, quantity of organics applied per unit volume of aeration capacity per unit time.

        3) Increase the quantity of organics applied. Usually requires:

            a) More activated sludge solids to stabilize the waste and maintain good sludge quality.

            b) More aeration volume (aeration time) to stabilize the waste and maintain good sludge quality

        4) Decrease the quantity of organics applied, usually requires:

            a) Fewer activated sludge solids to stabilize the waste and maintain good sludge quality.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.14.3

Slide 179.2/11.14.3 is a word slide which reads:

"Factors Affecting Sludge Quality

- Waste Characteristics
    - Quantity of Organics Applied
    - Concentration of Applied Organics
    - Type of Applied Organics
    - Hydraulic Load
    - Nutrients
    - Toxic or Inhibitory Substances
- Sludge Settleability
    - Type of Organisms
    - Solids Inventory
    - Aeration Basin Detention Time
    - Sludge Aeration Time
    - Temperature
- Aeration Rate"

b) Less aeration volume (aeration time) to stabilize the waste and maintain good sludge quality.

b. Concentration of applied organics:

1) May be measured as BOD, COD, TOC, TOD, etc.

2) Increase the concentration and usually require longer aeration time and/or more activated sludge solids to stabilize the waste and activated sludge solids to maintain good sludge quality.

3) Decrease the concentration and usually require shorter aeration time and/or fewer activated sludge solids to stabilize the waste and activated sludge solids to maintain good sludge quality.

c. Type of organics applied:

1) Some organics stabilize rapidly and require fewer activated sludge solids and/or shorter aeration time to stabilize the waste and activated sludge solids and maintain good sludge quality.

2) Some organics stabilize slowly and require more activated sludge solids and/or longer aeration time to stabilize the waste and activated sludge solids and maintain good sludge quality.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

3) Suspended materials are quickly adsorbed by the activated sludge solids but usually stabilize more slowly than dissolved materials.

d. Hydraulic load

1) Primary effects are on MLSS concentration and aeration detention time.

2) Increasing hydraulic load usually requires more activated sludge solids to maintain good sludge quality and to stabilize the applied organics.

3) Decreasing hydraulic load usually requires fewer activated sludge solids to maintain good sludge quality and to stabilize the applied organics.

e. Nutrients

1) Sludge solids require balanced nutrients (N, P, D.O., etc.) and sufficient nutrients to promote good growth, good stabilization and good sludge quality.

2) Nutrient imbalances can cause serious sludge quality problems.

f. Toxic or inhibitory substances

1) May cause kill or inhibition of activated sludge solids causing poor sludge quality and poor stabilization of applied organics.

2) System may be able to acclimate to low levels of toxic substances applied continuously.

2. Sludge Stability

a. Overstabilized or under stabilized sludges produce poor sludge quality.

1) Over stabilized sludges tend to settle rapidly, flocculate poorly and produce turbid supernates.

2) Under stabilized sludges tend to settle slowly but may flocculate well and produce clear effluents.

3) Best sludge quality and system performance occurs at some intermediate range of sludge stability.

4) The optimum range of sludge stability is system specific.

b. Types of organisms

1) Aerobic or facultative bacteria are most numerous organisms in activated sludge and are the workers that stabilize the waste.

2) Good sludge quality is associated with a balanced population of free and stalked ciliates, rotifers and protozoans.

3) Under stabilized sludges tend to have more protozoans and free swimming ciliates and filamentous bacteria may grow more readily.

LESSON OUTLINE | KEY POINTS & INSTRUCTOR GUIDE

4) Over stabilized sludges tend to have more stalked ciliates and rotifers and may flocculate less well than normal or understabilized sludges.

c. Solids inventory

1) Solids aeration time

a) Increasing solids aeration time increases sludge stability.

b) Decreasing solids aeration time decreases sludge stability.

2) Increasing solids inventory

a) Increases solids aeration time.

b) Reduces the F/M

3) Decreasing solids inventory

a) Decreases solids aeration time

b) Increases the F/M

d. Aeration Basin detention time

1) Increasing aeration basin detention time increases the oxidation pressures in the system and tends to produce a more stable sludge.

2) Decreasing aeration basin detention time decreases the oxidation pressure and tends to produce a less stable sludge.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

3) When aeration basin detention time decreases, more activated sludge solids are needed to accomplish the same degree of stabilization.

4) When aeration basin detention time increases, fewer sludge solids are required to accomplish the same degree of stabilization.

e. Sludge aeration time

1) Increasing sludge aeration time increases oxidative pressures and produces a more stabilized sludge.

   a) Increase solids inventory

   b) Increase aeration basin detention time

      1. Reduce hydraulic load to aeration basin

      2. Increase aeration volume

      3. Use sludge reaeration

2) Decreasing sludge aeration time decreases oxidation pressures and produces a less stabilized sludge.

   a) Decrease solids inventory

   b) Decrease aeration basin detention time

      1. Increase hydraulic load to aeration basin

      2. Decrease aeration volume

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. Don't reaerate sludge	
f. Temperature	
1) Increasing temperature increases biological activity permitting the same degree of stabilization to occur with:	
a) Lower solids inventory	
b) Shorter aeration basin detention time	
c) Shorter sludge aeration time	
2) Decreasing temperature decreases biological activity. To obtain the same degree of stabilization need:	
a) Higher solids inventory	
b) Longer aeration detention time	
c) Longer sludge aeration time	
3) Nitrification occurs more readily at higher temperatures.	
3. Aeration Rate	
a. Increasing aeration rate tends to increase the aeration basin D.O.	
b. Decreasing aeration rate tends to decrease aeration basin D.O.	
c. Aeration rate should be adjusted to maintain 1 - 3 mg/l D.O. and adequate mixing in the aeration basin.	

LESSON OUTLINE

d. Higher aeration rate tends to:

   1) Increase D.O. and mixing.
   2) Increase oxidation pressures and produce more stabilized sludge.
   3) Promote nitrification.
   4) Increase potential for mechanical shear of sludge floc.

e. Lower aeration rate tends to:

   1) Decrease D.O. and mixing.
   2) Decrease oxidation pressures and produce a less stable sludge.
   3) Discourage nitrification.
   4) Decrease potential for mechanical shear of sludge floc.

C. Controllable Variables in Activated Sludge Process

1. Five major controllable parameters

   a. Return Sludge Flow Rate (RSF)
   b. Waste Sludge Flow Rate (XSF)
   c. Aeration Rate
   d. Aeration Volume
   e. Aeration Contacting Pattern

2. Return sludge flow rate is a short term control used to maintain process balance and fine tune the system.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.14.4

Slide 179.2/11.14.4 is a word slide which reads:

"Controllable Variables in Activated Sludge Systems

- Return Sludge Flow Rate
- Waste Sludge Flow Rate
- Aeration Rate
- Aeration Volume
- Aeration Contacting Pattern"

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

a. Effect of return sludge flow rate change is observed in a time frame comparable to the aeration basin hydraulic detention time.

b. Increasing RSF

  1) Decreases aeration basin hydraulic detention time.

  2) Decreases final clarifier sludge detention time.

  3) Dilutes the return sludge concentration.

  4) Increases hydraulic load on final clarifier.

  5) Increases final clarifier solids handling capacity.

  6) Creates process condition which tends to produce a less stable, more slowly settling sludge.

c. Decreasing RSF

  1) Increases aeration basin hydraulic detention time.

  2) Increases final clarifier sludge detention time.

  3) Increases the return sludge concentration.

  4) Decreases hydraulic load on the final clarifier

  5) Decreases final clarifier solids handling capacity.

  6) Creates process conditions which tend to produce a more stable, faster settling sludge.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. Waste sludge flow rate is a long term control used to vary and maintain the solids inventory.	
a. Effect of a waste sludge flow rate change is observed in a time frame comparable to the mean cell residence time.	
b. Decreasing XSF	
1) Increases solids inventory.	
2) Increases sludge aeration time. 3) Increases final clarifier sludge detention time. 4) Increases the final clarifier underflow solids concentration. 5) Decreases final clarifier solids handling capacity.	Items b(2) through b(5) assume separate sludge wasting from the final clarifier underflow. If wasting is from the return line or from the aeration basin mixed liquor, then decrease in wasting rate may not cause all these effects on the final clarifier underflow.
6) Creates process conditions which tend to produce a more stable, faster settling sludge.	
c. Increasing XSF	
1) Decreases solids inventory.	
2) Decreases sludge aeration time. 3) Decreases final clarifier sludge detention time. 4) Decreases final clarifier underflow solids concentration. 5) Increases final clarifier solids handling capacity.	Items c(2) through c(5) assume separate sludge wasting from the final clarifier underflow. If wasting is from the return line or from the aeration basin mixed liquor, then a decrease in wasting rate may not cause all these effects on the final clarifier underflow.
6) Creates process conditions which tend to produce a less stable, slower settling sludge.	

4. Aeration Rate
    a. Try to maintain aeration basin D.O. in the range 1 - 3 mg/l.
    b. Maintain adequate mixing.
    c. Profile D.O. in the aeration basin to assure that there is at least 1.0 mg/l D.O. in all parts of the aeration basin.
    d. Low aeration basin D.O. (less than 1 mg/l) tends to promote filamentous bulking and may result in anoxic or anaerobic dead spots in the aeration basin.
    e. High aeration basin D.O. (greater than 6.0 mg/l) promotes bulking, increases overaeration potential, encourages nitrification.
5. Aeration Volume
    a. Plants with multiple aeration basins offer potential to vary aeration volume by controlling the number of basins in service.
    b. Increase aeration volume to produce a more stable, faster settling sludge.
    c. Decrease aeration volume to produce a less stable, slower settling sludge.
6. Aeration Contacting Patterns
    a. Separate sludge reaeration creates process conditions which tend to produce a more stable, faster settling sludge.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. Plants with capability to step feed influent wastewater offer potential to operate in process modes ranging from contact stabilization to conventional treatment. Both sludge aeration time and waste stabilization time (time the wastewater plus return sludge is under aeration) may be varied.	
c. Ability to step feed return sludge, i.e., control where return is introduced into the aeration basin, offer similar but not as complete flexibility.	Refer to Unit 11, Lesson 9 and 10, the Pullman Case History.
d. Capability to move to sludge reaeration operating mode offers a technique to protect the solids inventory from: 1) Excessively high hydraulic loading. 2) Toxic or inhibitory substances.	
D. Activated Sludge Process Control Parameters	Use Slide 179.2/11.14.5 Slide 179.2/11.14.5 is a word slide which reads:
1. Many parameters are used to provide process control information about the activated sludge process. The most useful are listed on Slide 179.2/11.14.5.	"Activated Sludge Process Control Parameters
2. F/M (Food to Microorganism Ratio) a. # Food applied/day/#solids inventory b. Helps balance solids inventory to applied load. c. Long term control parameter for controlling solids inventory through wasting changes.	· F/M · MCRT · Settleability · Respiration Rate · Microscopic Observations · Sludge Blanket Depth"

1) Increasing F/M normally produces slower settling, less stable sludge.

2) Decreasing F/M normally produces faster settling, more stable sludge.

3) Effect of a wasting rate change is normally observed in a time frame comparable to the MCRT.

d. Optimum F/M is plant specific.

3. MCRT (Mean Cell Residence Time)

a. #solids inventory/#solids removed/day

Note: # solids removed/day is the sum of the # solids deliberately wasted plus the # solids lost in the final clarifier overflow each day.

b. Long term control parameter for controlling solids inventory through wasting changes.

1) Increasing MCRT normally produces faster settling, more stable sludge.

2) Decreasing MCRT normally produces slower settling, less stable sludge

3) Effect of a wasting rate change is normally observed in a time frame comparable to the MCRT.

c. Optimum MCRT is plant specific.

4. Sludge Settleability

a. Laboratory determination of MLSS settling characteristics and best monitor of sludge quality.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

b. Used for short-term control of return activated sludge rates.

   1) Decreasing settling rate normally indicates need to reduce return sludge flow rate.

   2) Increasing settling rate normally indicates need to increase return sludge flow rate.

   3) Effect of a return sludge flow rate change normally observed in time frame comparable to the aeration basin detention time.

c. Used for long term control of solids inventory and wasting rates.

   1) Increasing settling rate normally indicates need to increase sludge wasting.

   2) Decreasing settling rate normally indicates need to decrease sludge wasting.

   3) Effect of wasting rate changes normally observed in time frame comparable to the MCRT.

5. Respiration Rate

   a. An indicator of biological activity (oxygen uptake) and hence sludge stability.

   b. Defined as mg O_2 used/hour/gram activated sludge solids and hence is independent of MLSS concentration.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

c. Two respiration rates are most useful in process control.

  1) MLSS respiration rate in the effluent from the aeration basin.

    a) Optimum range is usually 8 - 20 mg O_2/hr/gram, but is plant specific.

    b) Increasing MLSS RR indicates less stable sludge.

      1. Increase solids inventory

      2. Increase solids aeration time

    c) Decreasing MLSS RR indicates more stable sludge.

      1. Decrease solids inventory

      2. Decrease solids aeration time

  2) Respiration rate of a mixture of aeration basin influent and return activated sludge.

    a) Monitors applied load.

    b) Potential to identify toxic or inhibitory substances.

d. Oxygen uptake rate of the final effluent can be used to estimate effluent BOD in 2-4 hours test.

6. Microscopic Observations

  a. Normal sludge contains balanced

population of free swimming and stalked ciliates, protozoans and rotifers.

b. Movement toward free swimming ciliates and protozoans as predominant organisms indicates a younger, less stable sludge.

c. Movement toward rotifers and stalked ciliates as predominant organisms indicates an older, more stable sludge.

d. The optimum population balance is plant specific. Control responses should be made if shifts in the balance of predominant organisms occurs.

7. Sludge Blanket Depth in the final clarifier

   a. Try to keep blanket in the lower 1/3 - 1/2 of the final clarifier.

   b. Rising blanket may indicate:

      1) Change in sludge quality.

      2) Increase in solids inventory.

      3) Insufficient return or wasting rates.

      4) Final clarifier design or O & M problems.

   c. Falling blanket may indicate:

      1) Change in slduge quality.

      2) Decrease in solids inventory.

      3) Excessive return or wasting rates.

LESSON OUTLINE

8. Conclusion

   a. Each process control parameter provides somewhat different process control information. No single parameter yields total information needed to control the process by adjusting controllable variables.

   b. Best control can be achieved by monitoring and responding to all the process control parameters. Together the parameters provide complete process control information. (The whole is greater than any of its parts.)

   c. Troubleshooters must look at all the parameters to successfully identify the cause of process control problems and to recommend correct process control responses.

E. Final Clarifier Solids Settling Problems

1. Bulking means a sludge which settles very slowly and does not concentrate. Usually associated with SVI > 200.

2. Frequently all final clarifier solids separation problems are erroneously referred to as sludge bulking.

3. Many factors may cause final clarifier settling problems as noted on Slide 179.2/11.14.6.

4. If the problems are caused by a poorly designed or an imporperly operated and maintained final clarifier, process control changes which impact sludge quality may not be effective in solving the problem.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.14.6

Slide 179.2/11.14.6 is a word slide which reads:

"Final Clarifier Solids Settling Problems

- Final Clarifier Physical Defects
  - Design
  - O & M
- Sludge Quality
  - Low Sludge Density
  - Poor Floc Formation
  - Poor Compaction"

LESSON OUTLINE

5. Process control changes can solve sludge quality related settling problems and sometimes may create process conditions which permit acceptable operation in spite of design or O & M defects in the system.

II. Questions, Answers, Discussion (25 minutes)

Use remaining time to respond to questions from the class and for general discussion about activated sludge process operations and troubleshooting.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/11.14.7

Slide 179.2/11.14.7 is a blank

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 11: Activated Sludge

Lesson 14: Unit Summary

Trainee Notebook Contents

References T11.14.1

1251

REFERENCES

1. Benefield, L. D., Randall, C. W., and King, P. H., "Process Control by Oxygen - Uptake and Solids Analysis," *Journal Water Pollution Control Federation*, 47, 2498 (October, 1975).

2. Bryant, J. O., *Continuous Time Simulation of the Conventional Activated Sludge Wastewater Renovation System*, Ph. D. Dissertation, Clemson University, Clemson, South Carolina (August, 1972).

3. Camp, T. R., "Sedimentation and the Design of Settling Tanks," *Transactions American Society of Civil Engineers*, 111, 895 (1946).

4. Dick, R. I., "Folklore in the Design of Final Settling Tanks," *Journal Water Pollution Control Federation*, 48, 633-644 (April, 1976).

5. Dick, R. I., "Role of Activated Sludge Final Settling Tanks," *Journal of the Sanitary Engineering Division, American Society of Civil Engineers*, 96(SA2), 423-436 (April, 1970).

6. Eckhoff, D. W. and Jenkins, D., *Activated Sludge Systems: Kinetics of the Steady and Transient States*, Report No. 67-12, SERL, University of California, Berkeley, California (December, 1967).

7. Hatfield, W. D., "Operation of the Activated Sludge Process," *Journal Water Pollution Control Federation*, 38, No. 6 (June, 1966).

8. Hegg, B. A. and Burgeson, J. R., "An Integrated Approach to Control Testing and Basic Kinetics," presented at the 47th WPCF Conference, Denver, Colorado (October, 1974).

9. *Inspectors Guide for Evaluation of Municipal Wastewater Treatment Plants*, EPA 430/9-79-010, U. S. Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (April, 1979).

10. Jahn, T. C. *How to Know the Protozoa*, William C. Brown Publishers (1976).

11. Johnson, D. S., et. al., "Operational Control of an Activated Sludge Process by Biomass Respiration Rate," presented at the 44th Annual Pacific Northwest Pollution Control Association Meeting, Portland, Oregon (November 2 - 4, 1977).

12. Johnson, D. S., Bhagat, S. K., Asano, T., and Ongerth, J. E., "Operation of an Activated Sludge Process Using Biomass Respiration Rates to Accommodate Fluctuating Hydraulic and Organic Loads," Final Report, Department of Civil and Environmental Engineering, Washington State University, Pullman, Washington (July, 1976).

13. Joyce, R. J., Ortman, C., Zickefoose, C., "Optimization of an Activated Sludge Plant Using TOC, Dissolved Oxygen, Respiration Rate and Sludge Settling Volume Data," presented at the WWEMA Ind. Water and Pollution Conference, Detroit, Michigan (April, 1974).

14. Ludzack, F. J., "Dissolved Oxygen Analysis--Activated Sludge Control Testing," slide-tape XT-43, U. S. Environmental Protection Agency, National Training and Operational Technology Center, Cincinnati, Ohio (1971).

15. *Manual of Wastewater Operations*, Texas Water Utilities Association, Austin, Texas (1971).

16. Meers, J. E., "Activated Sludge Process Control," *The Digester*, Illinois Environmental Protection Agency, Springfield, Illinois (May, 1975).

17. Metcalf & Eddy, Inc., *Wastewater Engineering Treatment Disposal Reuse*, Chapters 9 and 10, McGraw-Hill Book Company, New York, New York (2nd edition, 1979).

18. Nemke, J., "Visual Observations Can be Process Control Aids," *Deeds and Data*, September, 1975.

19. *Operation of Wastewater Treatment Plants*, *MOP/11*, Chapters 11 and 12, Water Pollution Control Federation, Washington, D.C. (1976).

20. *Operators Pocket Guide to Activated Sludge*, Parts I and II, ST[illegible]AM Engineers, Inc., Portland, Oregon (1975).

21. *Package Treatment Plant Operations Manual*, EPA 430/9-77-005, U. S. Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (April, 1977).

22. Pipes, W. O., "Bulking of Activated Sludge, *Advances in Applied Microbiology*, No. 9, 1967.

23. Prescott, G. W., *How to Know Freshwater Algae*, William C. Brown Publishers (1970).

24. *Process Control Manual for Aerobic Biological Wastewater Treatment Facilities*, EPA 430/9-77-006, U. S. Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (March, 1977).

25. Sherrard and Kincannon, "Operational Concepts for the Activated Sludge Process," *Water and Sewage Works* (March, 1974).

26. *Standard Methods for the Examination of Water and Wastewater*, A.P.H.A., A.W.W.A. and W.P.C.F. (14th edition, 1975).

27. Steward, M. J., "Activated Sludge Process Variations. The Complete Spectrum," Article in three parts, *Water and Sewage Works*, *111*(RN), pp. R241-R262, November 30, 1964.

28. *Wastewater Treatment Plant Operator Training Program Intermediate Course*, Water Pollution Control Federation, Washington, D.C.

29. West, A. W., *Operational Control Procedures for the Activated Sludge Process*, Parts I, II, IIIA, IIIB and Appendix, U. S. Environmental Protection Agency, National Training and Operational Technology Center, Cincinnati, Ohio.

30. West, A. W., *Updated Summary of the Operational Control Procedures for the Activated Sludge Process*, U. S. Environmental Protection Agency, National Training and Operational Technology Center, Cincinnati, Ohio.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 12: Solids Handling

Unit 12 of 15 Units of Instruction

Lessons in Unit: 5 Recommended Time: 5 2/3 hours

Rationale for Unit: Solids handling systems represent about 50% of the total operating and maintaining costs in wastewater treatment facilities. Many wastewater treatment facility problems are caused by inability to adequately waste and dispose solids generated in the treatment processes. Too often attention focuses on the liquid stream treatment process without adequate consideration of the solids processing and disposal system. This unit of instruction presents troubleshooting information on the most frequently encountered solids handling unit operations and unit processes.

Trainee Entry Level Behavior: Trainees should have achieved the learning objectives specified for Unit of Instruction 2, *Elements of Troubleshooting*, before beginning this unit of instruction.

Trainee Learning Objectives: At the conclusion of this unit the trainee should be able to:

1. From memory, describe the purposes of solids handling in wastewater treatment and cite examples of solids handling processes and equipment.
2. From memory, describe the anaerobic digestion process in terms that can be understood by the majority of plant operators.
3. From memory, compare and contrast the various types of anaerobic digester systems and draw simple schematic diagrams of each process.
4. Demonstrate an ability to recognize anaerobic digester systems and components by identifying the type of system and component parts when shown a photograph of an aerobic digester.
5. From memory, list the process control parameters which should be measured and monitored to affect anaerobic digester process control and troubleshooting and explain the significance of each parameter.

6. From memory, describe normal start-up and operational control procedures for anaerobic digesters.

7. Using references, list clues, factors and process control parameter indicators of anaerobic digester problems, assign a probable cause for each problem and recommend appropriate corrective actions for each problem cause.

8. Demonstrate proper troubleshooter behavior and apply the process of troubleshooting in an oral interview role playing exercise.

9. Explain the importance of proper troubleshooter behavior by observing and constructively critiquing other trainees' performances during a role playing troubleshooting exercise.

10. Demonstrate his/her ability to organize and conduct an oral interview to obtain essential technical data for troubleshooting an anaerobic digester problem and recognize how the interview technique must be adapted to respond to the personality and attitude of the plant operator.

11. Demonstrate his/her understanding of anaerobic digester operations and troubleshooting by successfully solving the problems presented.

12. From memory, describe and explain the purposes and functions of the following solids handling processes:

    a. Gravity thickening
    b. Dissolved air flotation thickening
    c. Centrifugation
    d. Aerobic digestion
    e. Sludge drying beds
    f. Vacuum filtration

13. Using references, list the operating parameters and their expected ranges for evaluating the operational performance of the solids handling unit processes and operations listed in Objective 1.

14. Using references, list common operational problems which occur with the solids handling unit processes and operations listed in Objective 1 and describe how each problem may be diagnosed and corrected.

15. Describe actual solids handling problems which have been encountered in the field by trainees in the class and discuss how the process of troubleshooting was applied to solve the problems.

16. Given a trainee problem statement about an unsolved solids handling problem, apply the process of troubleshooting to develop an approach to solving the problem given.

17. Demonstrate his/her ability to apply the process of troubleshooting to analyze and solve a vacuum filtration solids handling problem which has deteriorated to the point that the entire plant has been affected.

18. Describe why a wastewater treatment plant must be viewed as an integrated system of component processes and operations and cite one example of how a malfunction in one part of the plant can affect other operations and processes in the plant.

Sequencing and Pre-Course Preparation for the Unit: Unit 12, *Solids Handling*, is presented as five lessons.

Lesson 1: Anaerobic Digestion

Recommended Time: 60 minutes

Purpose: Anaerobic digestion is a frequently used process to stabilize wastewater treatment process solids. This anaerobic biological process has the advantage of generating reusable energy in the form of methane gas and is again gaining popularity as a method for solids stabilization in wastewater treatment. Because the microorganisms involved in anaerobic digestion are sensitive to environmental and process conditions, the process is subject to a variety of upsets which can be avoided or cured with proper process control and problem solving. This lesson introduces the topic of solids handling, reviews the theory of anaerobic digestion and discusses common problems encountered in the operation of anaerobic digesters.

Training Facilities:

1. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees in groups of four.
2. Instructor table with lectern.
3. Large projection screen (6' x 6' minimum) and chalkboard in front of room and readily visible to all trainees.
4. Easel with pad.
5. 35mm carousel projector with remote control changer at instructor table.

6. At least four empty carousel trays.
7. Overhead projector.
8. Chalk, felt-tip markers and erasers.
9. Six to eight chairs randomly spaced at back and sides of room for visitors.

Pre-Course Preparation:

1. Trainee Texts:
   a. Order and have available at each trainee seating position *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA 430/9-78-001, Municipal Operations Branch, U. S. Environmental Protection Agency, Washington, D.C. (January, 1978).
2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:
   a. *Trainee Notebook*, pages T12.1.1 - T12.2.2, "Sludge Treatment Process."
   b. *Trainee Notebook*, page T12.1.3, "Schematic Diagrams of Standard and High Rate Anaerobic Digester System."
   c. *Trainee Notebook*, page T12.1.4, "Start-up Procedures for Anaerobic Digesters."
3. Trainee Handout materials

   Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plan:
   a. None required for Lesson 1.

Instructional Approach: Illustrated lecture with class discussion.

Lesson 2: Problem Solving in Anaerobic Digestion

Recommended Time: 110 minutes

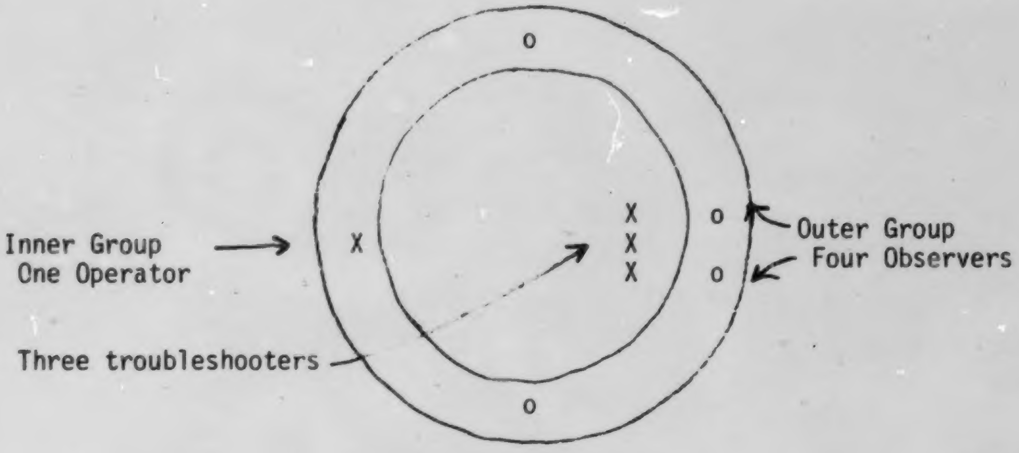
Purpose: This lesson requires the trainees to practice applying the process of troubleshooting to anaerobic digestion problems using a role playing simulation exercise. Three trainees from each four person work group role play troubleshooters while the fourth member of the work group role plays the operator. The exercise is conducted using a "fish bowl" technique in which a second four person work group observes the role playing exercise and then critiques the performance of the troubleshooters. Two problems are solved so that each work group participates in both observer and troubleshooter roles. The thrust of the exercise is to emphasize the importance of oral communication and attitude in troubleshooting. In this exercise proper application of the process of troubleshooting and interpersonal communication skills are more important than is solution of the technical problems provided.

Training Facilities: The classroom should be set up to accommodate groups of eight trainees. If possible, to avoid distraction from one group to another, separate rooms should be used for each group of eight.

Each group of 8 consists of two four-person groups, an "inner" group who are actually participating in the role playing-problem solving and an "outer" group who are observing.

Each "inner" group consists of three troubleshooters and one trainee who is playing the operator's role.

Each group of eight should be arranged as in the diagram:



Pre-Course Preparation:

1. Trainee Texts:

   a. As specified for Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, page T12.2.1, "Instructions to Troubleshooters: Problem 1."

   b. *Trainee Notebook*, page T12.2.2, "Instructions to Troubleshooters: Problem 2."

3. Trainee Handout materials

   Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plan.

   a. *Instructor Notebook*, pages H12.2.1 - H12.2.2, "Instructions to Operators: Problem 1."

   b. *Instructor Notebook*, pages H12.2.3 - H12.2.5, "Instructions to Operators: Problem 2."

Instructional Approach: Trainee problem solving in a role playing exercise using the "fish bowl" technique.

Lesson 3: Other Methods of Solids Handling

Recommended Time: 90 minutes

Purpose: Many methods in addition to anaerobic digestion are used in solids handling and conditioning. This lesson presents problem identification and troubleshooting information on gravity thickening, dissolved air flotation thickening, centrifugation, aerobic digestion, sludge drying beds and vacuum filtration. Heat treatment and incineration are not discussed in the course.

Training Facilities: As specified for Lesson 1.

Pre-Course Preparation:

1. Trainee Texts

   a. As specified for Lesson 1.

1260

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, pages T12.3.1 - T12.3.4, "Typical Performance Characteristics of Solids Handling Systems."

   b. *Trainee Notebook*, pages T12.3.5 - T12.3.11, "Troubleshooting Guide - Solids Handling."

3. Trainee Handout materials

   Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plan.

   a. None required for Lesson 3.

Instructional Approach: Illustrated lecture with class discussion.

Lesson 4: Tall Tales or "Where Did All That Sludge Come From?"

Recommended Time: 40 minutes

Purpose: This lesson encourages trainees to share their experiences in troubleshooting solids handling problems by providing an opportunity for trainees to describe and discuss problems which they have seen. Trainees should be encouraged to surface problems which they may have encountered but for which they have no solution and to use class time to develop an approach to solving some of these problems.

Training Facilities: As specified for Lesson 1.

Pre-Course Preparation:

1. Trainee Texts

   a. As specified for Lesson 1.

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. None required for Lesson 4.

3. Trainee Handout materials

Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plan.

a. None required for Lesson 4.

Instructional Approach: Class discussion, questions and answers.

Lesson 5: Applying the Process of Troubleshooting

Recommended Time: 40 minutes

Purpose: The unit operations and processes divisions used to structure the course *Troubleshooting O & M Problems in Wastewater Treatment Facilities* tends to focus trainee attention to a small portion of the plant as the site of problem occurrence and its effects on the treatment plant. This problem illustrates how a solids handling problem can cause difficulties in the liquid processing units (activated sludge units). The cause of the problem and its solution are remote from the indicators of the problem given to the class. The problem causes the trainees to view the entire treatment plant as one integrated system where a malfunction in one part of the system may affect all other parts of the system.

Training Facilities: As specified for Lesson 1.

Pre-Course Preparation:

1. Trainee Texts:

a. As specified for Lesson 1.

2. *Trainee Notebook* materials

Reproduce and insert into the *Trainee Notebook* the following:

a. *Trainee Notebook*, page T12.5.1, "References."

3. Trainee Handout materials

Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plan.

a. None required for Lesson 5.

Instructional Approach: Trainee problem solving with trainees role playing troubleshooters while the instructor role plays the operator.

Presentation Options for Course Director: The unit on *Solids Handling* is one of the major subject areas covered in this course. It contains five lessons and, as written, required a presentation time of 5 hours, 40 minutes. This unit could be expanded or shortened depending on the needs of the student group. However, in relation to a total course time of 28 to 40 hours, the existing time of presentation is appropriate. If the unit needs to be significantly shortened for any reason, it is suggested that lesson 5, and then lesson 4 be reduced. However, the minimum time for presenting the significant points in this unit is 4½ hours, reducing the unit to lessons 1 through 3, with some additional discussion and a summary.

Some of the presentation options are as follows:

Lesson 1 - Anaerobic Digestion: The existing 1 hour lesson is sufficient for trainees with the proper entry level background to the course. For trainees below that level, additional background material may have to be presented and additional time would be required.

Lesson 2 - Problem Solving in Anaerobic Digestion - "Fishbowl Technique": This lesson reinforces all of the emphasis on the *Process of Troubleshooting* which is presented throughout the course. In effect, it is a test to see whether the trainees have acquired the skills and sensitivities which this course attempts to present. While it is possible to develop variations to the existing lesson material, this lesson is an essential element to the course and should be used as the course developers intended.

Lesson 3 - Other Methods of Solids Handling: This lesson covers some very important facets of solids handling. However, it is one of the more factual, "straightforward" lessons in the course. This lesson is very lecture oriented with more limited trainee involvement in problem solving.

One option for this unit would be to expand it by using slides which show all of the equipment which is described in the lessons. A second option, which could be valuable if time permits, would be to have the class visit a treatment plant that contains and uses the processes described. A third option would be to cover additional topics. This should be done only if a) other processes are common in the region where the course is held, and b) the time is broken up so that the presentation of this material is not continuous.

Finally, the Course Director should eliminate from this unit any solids handling process which is not common in the area where the course is being given.

Lesson 4 - Tall Tales or "Where Did All That Sludge Come From?": This lesson has proven to be very popular with trainees taking the course. It affords them an opportunity to discuss problems thay have seen and experienced.

If the solids Handling lesson must be reduced to below 5 hours, this lesson may have to be reduced or deleted. However, it is recommended that it be kept intact and used as provided in the lesson plan materials.

Lesson 5 - Applying the Process of Troubleshooting: This lesson provides a useful summary to this very important unit and should be included if possible. However, if the lesson on solids handling needs to be shortened for any reason, this lesson should be the first to be deleted.

Summary of Unit of Instruction 12: Solids Handling

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Anaerobic Digestion 60 minutes	1. Describe anaerobic digestion in understandable terms	1. Importance of solids handling and solids handling problems	1. Instructor to follow lesson outline	1. *Trainee Notebook*, pages T12.1.1 - T12.1.4
	2. Identify and sketch various types of digesters	2. Communication problems between engineers and operators	2. Use of slide series and slide key	2. *Instructor Notebook*, pages 12.1.1 - 12.1.18
	3. Identify anaerobic digestion process parameters to measure	3. Significant process parameters in anaerbic digestion	3. Stimulation of trainee discussion by instructor	3. Slides 179.2/12.1.1 - 179.2/12.1.34
	4. List operating problems and approaches to investigating and correcting problems in anaerobic digestion	4. Troubleshooting anaerobic digestion problems		4. Process of Troubleshooting Chart, *Trainee Notebook*, page T2.2.8
				5. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*
2. Problem Solving in Anaerobic Digestion - "Fishbowl Technique	1. Employ the Process of Troubleshooting	1. Troubleshooting techniques	1. Role playing by trainee groups of troubleshooters	1. "Instructions to Troubleshooters: Problem 1," *Trainee Notebook*, page T12.2.1

Summary of Unit of Instruction 12: Solids Handling (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
110 minutes	2. Experience problems confronted by treatment plant operators	2. Relationships with operators	2. Observation of techniques by trainee reporters	2. "Instructions to Troubleshooters: Problem 2, *Trainee Notebook*, page T12.2.2
	3. Critique the troubleshooting techniques of others	3. Troubleshooter behavior	3. Feedback on troubleshooting techniques given by trainee observers	3. *Instructor Notebook*, pages 12.2.1 - 12.2.11
	4. Have their troubleshooting techniques critiqued	4. Feedback on using troubleshooting techniques and troubleshooting behavior	4. Class discussion of results and and experiences	4. "Instructions to Operators: Problem 1", *Instructor Notebook*, pages H12.2.1 - H12.2.2 (Reproduce for distribution)
				5. "Instructions to Operators: Problem 2, *Instructor Notebook*; pages H12.2. - H12.2.5 (Reproduce for distribution)
3. Other Methods of Solids Handling 90 minutes	1. List and identify six unit processes of solids handling	1. Understanding normal process	1. Use lesson outline, with word slides as focal point of class discussion	1. *Trainee Notebook*, pages T12.3.1 - T12.3.11

Summary of Unit of Instruction 12: Solids Handling (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
	2. Describe normal operations and evaluation tests for each process	2. Evaluating process operations	2. Picture slide series on aerobic digestion	2. *Instructor Notebook*, pages 12.3.1 - 12.3.32
	3. Identify operating problems, causes and corrective actions for each process	3. Troubleshooting common operational problems	3. Frequent use of *Trainee Notebook* materials	3. Slides 179.2/12.3.1 - 179.2/12.3.53
			4. Delete processes not found in area where course is given	4. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*
4. Tall Tales or "Where Did All That Sludge Come From?"	1. Identify actual solids handling problems and the approaches to solving them	1. Solids handling problems encountered in the region where the course is presented	1. Trainees provide actual problems, instructor screens and selects problems for discussion	1. *Instructor Notebook*, pages 12.4.1 - 12.4.3
40 minutes	2. Recommend alternative approaches to solving problems		2. Selected problems are discussed by class	

Summary of Unit of Instruction 12: Solids Handling (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
5. Applying the Process of Troubleshooting 40 minutes	1. Analyze and troubleshoot a vacuum filtration problem	1. Case study-actual problem of plant failure due to improper solids handling	1. Instructor presents case study problem as the "operator"	1. Process of Troubleshooting Chart, *Trainee Notebook*, page T2.2.8
	2. Discuss the connection between solids handling and overall treatment plant performance		2. Trainees "troubleshoot" the problem, advise on its solution	2. *Instructor Notebook*, pages 12.5.1 - 12.5.7

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 12: Solids Handling

Lesson 1: Anaerobic Digestion

Lesson 1 of 5 lessons

Recommended Time: 60 minutes

Purpose: Anaerobic digestion is a frequently used process to stabilize wastewater treatment process solids. This anaerobic biological process has the advantage of generating reusable energy in the form of methane gas and is again gaining popularity as a method for solids stabilization in wastewater treatment. Because the microorganisms involved in anerobic digestion are sensitive to environmental and process conditions, the process is subject to a variety of upsets which can be avoided or cured with proper process control and problem solving. This lesson introduces the topic of solids handling, reviews the theory of anaerobic digestion and discusses common problems encountered in the operation of anaerobic digesters.

Trainee Entry Level Behavior: The trainee should have achieved the learning objectives specified for Units of Instruction 1 and 2 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. From memory, describe the purposes of solids handling in wastewater treatment and cite examples of solids handling processes and equipment.
2. From memory, describe the anaerobic digestion process in terms that can be understood by the majority of plant operators.
3. From memory, compare and contrast the various types of anaerobic digester systems and draw simple schematic diagrams of each process.
4. Demonstrate an ability to recognize anaerobic digester systems and components by identifying the type of system and component parts when shown a photograph of an aerobic digester.
5. From memory, list the process control parameters which should be measured and monitored to affect anaerobic digester process control and troubleshooting and explain the significance of each parameter.

6. From memory, describe normal start-up and operational control procedures for anaerobic digesters.

7. Using references, list clues, factors and process control parameter indicators of anaerobic digester problems, assign a probable cause for each problem and recommend appropriate corrective actions for each problem cause.

Instructional Approach: Illustrated lecture with class discussion.

Lesson Schedule: The 60 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 10 minutes	Introduction to Solids Handling Systems
10 - 35 minutes	Fundamentals of Anaerobic Digestion
35 - 60 minutes	Troubleshooting Anaerobic Digesters

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, page T12.1.1 - T12.1.2, "Sludge Treatment Process."

2. *Trainee Notebook*, page T12.1.3, "Schematic Diagrams of Standard and High Rate Anaerobic Digester System."

3. *Trainee Notebook*, page T12.1.4, "Start-up Procedures for Anaerobic Digesters."

4. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 295 - 315.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 12.1.1 - 12.1.28, Unit 12, Lesson 1.

2. Slides 179.2/12.1.1 - 179.2/12.1.34.

Instructor Materials Recommended for Development: None

Additional Instructor References:

1. *Operation of Wastewater Treatment Plants, MOP-11*, pages 249-284, Water Pollution Control Federation, Washington, D.C. (1976).

2. *Process Design Manual, Sludge Treatment and Disposal*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (October, 1974).

3. *Operations Manual, Anaerobic Sludge Digestion*, Municipal Operations Branch, U.S. Environmental Protection Agency, Washington, D.C. (February, 1976).

4. Metcalf and Eddy, Inc., *Wastewater Engineering Treatment Disposal Reuse*, pages 573-694, McGraw-Hill Book Company, New York (2nd edition, 1979).

5. Gould, Robert F., ed., *Anaerobic Biological Treatment Processes*, Advances in Chemistry Series, American Chemical Society, New York (1971).

6. McCarty, Perry L., "Anaerobic Waste Treatment Fundamentals," *Public Works Magazine*, 95, Series of four articles (September through December, 1964).

7. *Manual of Wastewater Operations*, Texas Water Utilities Association, Austin, Texas (1971).

8. *Inspectors Guide for Evaluation of Municipal Wastewater Treatment Plants*, EPA 430/9-79-010, Municipal Operations Branch, U.S. Environmental Protection Agency, Washington, D.C. (1979).

Classroom Set-Up:

1. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees in groups of four;
2. Instructor table with lectern;
3. Large projection screen (6' x 6' minimum) and chalkboard in front of room and readily visible to all trainees;
4. Easel with pad;
5. 35mm carousel projector with remote control changer at instructor table;
6. At least four empty carousel trays;
7. Overhead projector;
8. Chalk, felt-tip markers and erasers;
9. Six to eight chairs randomly spaced at back and sides of room for visitors.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Introduction to Solids Handling (10 minutes)	Use Slide 179.2/12.1.1 Slide 179.2/12.1.1 is a blank
A. Proper disposal of solids - is one half the challenge of designing and operating a wastewater treatment plant.	
1. Concern for a good effluent often puts the question of solids in the background.	Use Slide 179.2/12.1.2 Slide 179.2/12.1.2 is a word slide which reads:
2. Solids volume is very large - presents handling and processing problems.	"Solids Handling Systems"
B. Reuse of solids - In certain situations the reuse of solids may be economical and productive - at least more economical than other forms of disposal.	
1. Land spreading of sludge is most common form of reuse.	
2. Processing into dry fertilizer is practiced in some places with varying degrees of success.	
3. There are now processes that can stabilize sludges into construction type materials.	
C. Troubleshooting of Solids Handling Problems	
1. Problems with solids in treatment plant are numerous and frequent.	
2. Solids problems can easily lead to many other operational problems among the treatment processes.	
D. Purposes of Solids Handling	Use Slide 179.2/12.1.3 Slide 179.2/12.1.3 is a word slide which reads:
1. Use Slide 179.2/12.1.3 to review solids treatment unit processes and their functions:	"Sludge Treatment Processes
a. Thickening (Blending)	

LESSON OUTLINE

1) Water removal
2) Volume reduction
3) Post process efficiencies
4) Blending

b. Stabilization (Reduction)

1) Pathogen destruction
2) Volume and weight reduction
3) Odor control
4) Putrescibility control
5) Gas production

c. Conditioning (Stabilization)

1) Improve dewatering or thickening rate
2) Improve solids capture
3) Improve compactability
4) Stabilization

d. Dewatering

1) Water removal
2) Volume and weight reduction
3) Change to damp cake
4) Reduces fuel requirements for incineration/drying

e. Heat Drying

1) Water removal

KEY POINTS & INSTRUCTOR GUIDE

Thickening (Blending)
Stabilization (Reduction)
Conditioning(Stabilization)
Dewatering
Heat Drying
Reduction (Stabilization)
Final Disposal"

Refer class to *Trainee Notebook*, page T12.1.1, "Sludge Treatment Processes"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
2) Sterilization	
3) Utilization	
f. Reduction (Stabilization)	
1) Destruction of solids	
2) Water removal	
3) Conversion	
4) Sterilization	
g. Final Disposal	
1) Utilization (cropland)	
2) Utilization (energy)	
3) Utilization (land reclamation)	
4) Disposal (landfill)	
5) Disposal (ocean)	
2. Identify solids handling equipment, processes or operations associated with each unit process	Refer class to *Trainee Notebook*, page T12.1.2, "Unit Processes - Sludge Processing and Disposal"
a. Thickening (Blending)	
1) Gravity	
2) Flotation	
3) Centrifuge	
b. Stabilization (Reduction)	
1) Composting	
2) Aerobic digestion	
3) Anaerobic digestion	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
4) Lime treatment	
5) Chlorine treatment	
6) Heat treatment	
c. Conditioning (Stabilization)	
1) Chemical	
2) Elutriation	
3) Heat treatment	
d. Dewatering	
1) Filter press or belt filter	
2) Drying beds	
3) Centrifuge	
4) Rotary vacuum filter	
5) Horizontal filter	
6) Cylindrical screw	
7) Lagoons	
e. Heat Drying	
1) Flash dryer	
2) Multiple hearth	
3) Tray dryer	
4) Spray dryer	
f. Reduction (Stabilization)	
1) Incineration	
2) Wet air oxidation	
3) Pyrolysis	

g. Final Disposal

1) Cropland

2) Land reclamation

3) Power generation

4) Sanitary landfill

5) Ocean disposal

3. Note that this course will cover only the more commonly used solids handling and conditioning operations and processes.

a. Anaerobic digestion

b. Aerobic digestion

c. Drying beds

d. Thickening

1) Gravity

2) Dissolved air floatation

e. Vacuum filters

f. Centrifuge

E. Purpose of This Lesson

1. To identify and investigate problems that occur in various solids handling processes.

2. To review the causes of such problems, how they are identified, and how they are solved.

3. To stress the use of the Process of Troubleshooting in solving solids handling problems.

Use Slide 179.2/12.1.4
Slide 179.2/12.1.4 is a word slide which reads:

"Purpose of Lesson

1. To identify and investigate problems
2. To review the causes of such problems, how they are identified, how they are solved

LESSON OUTLINE

4. To focus on troubleshooter behavior and the means for troubleshooters to provide technical assistance.

II. Fundamentals of Anaerobic Digestion (25 minutes)

A. Description of anaerobic digestion (in terms that the operators of small plants might use)

1. Bacteria in the sludge help to liquify and gasify the organics in the sludge.

2. The bacteria produce carbon materials and energy.

3. Digestion does not completely stabilize the sludge.

4. The digester can be described as being a big "stomach," doing the same things that a person's stomach does.

B. Contrast this description with the textbook description, which if used by the troubleshooter, would probably "turn off" the operator forever, and make technical assistance impossible.

1. Textbook description

"Anaerobic digestion of domestic sewage sludge is the process whereby anaerobic and facultative bacteria liquify and gasify the organic portion

KEY POINTS & INSTRUCTOR GUIDE

3. To stress the use of the Process of Troubleshooting
4. To focus on troubleshooter behavior and ways in which troubleshooters can provide technical assistance"

Refer class to *Trainee Notebook*, page T2.2.8, "The Process of Troubleshooting"

Use Slide 179.2/12.1.5
~~Slide 179.2/12.1.5~~ is a blank

Guide: In addition to its content, this section emphasizes the importance of communication in troubleshooting and in dealing with operators.

In communicating or troubleshooting, do not attempt to be the "smartest" person in the world.

Key Point: The basic problem in engineer communication with operators is too much theory

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

of the sludge in order to obtain energy and certain elements, such as carbon, for the synthesis of their protoplasmic production. Anaerobic digestion is not a complete stabilization process since many of the organic constituents resist biological decomposition; for example, carbohydrates and short-chained fatty acids are catabolized more rapidly in the process than fats and oils."

C. Emphasize the importance of gas production as a part of the process of anaerobic digestion. It is an indicator of the health of the process.

1. Gas components

   a. Methane: 65 - 70%

   b. Carbon Dioxide: 30 - 35%

   c. H_2S, H_2: Traces

   d. CO_2 greater than 35% indicates possible problem

2. Gas yield

   a. Solids Feed 0.2 - 0.3 # solids per day per capita

   b. Gas yield

      1) Unheated digester
      0.32 - 0.56 ft^3/capita/day

      2) Heated digester

      0.56 - 0.74 ft^3/capita/day

Refer class to pages 296-298, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*

LESSON OUTLINE

D. Process Diagrams

1. Low rate (standard) digestion
    - a. Unheated
    - b. Unmixed
2. High rate digestion
    - a. Most digesters are now high rate digesters
    - b. Heated
3. Two-stage anaerobic digestion
    - a. Primary digester
        - 1) Usually fixed cover
        - 2) Some are converted from secondary digesters with floating cover
        - 3) Heated
        - 4) Completely mixed - mechanical or gas mixing
        - 4) Piping layout may cause operational difficulties in converted digesters
    - b. Secondary digester
        - 1) May have floating or gas holder cover
        - 2) Unmixed and unheated
        - 3) Principal function is to separate solids
4. Anaerobic contact digestion
    - a. This variation is usually achieved

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/12.1.6
Slide 179.2/12.1.6 is a schematic diagram showing an unmixed, unheated low rate digester.

Use Slide 179.2/12.1.7
Slide 179.2/12.1.7 is a schematic diagram showing a two-stage anaerobic digester.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
in piping arrangements by having capability to continuously recycle digested solids from the secondary digester to the primary digester.	
b. Continuous "seeding" permits higher loadings, shorter detention times.	
5. Refer class to page 299, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, and to page T12.1.3, *Trainee Notebook*, for summary of loading factors for high rate and low rate (standard rate) digesters.	
a. High Rate	
1) MCRT: 10-20 days	Note: Values given are recommended operating parameters or loading rates.
2) Lbs VSS/ft^3/day: 0.15-0.40	
3) ft^3/capita	
a) Primary sludge: 1.33-2.0	
b) Primary sludge plus trickling filter humus: 2.66-3.33	
c) Primary plus waste activated sludge: 2.66-4.0	
b. Low Rate	
1) MCRT: 30-60 days	
2) Lb VSS/ft^3/day: 0.03-0.1	
3) ft^3/capita	
a) Primary Sludge: 2-3	7
b) Primary sludge plus trickling filter humus: 4-5	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
c) Primary plus waste activated sludge: 4-6	
E. Components of an Anaerobic Digester	
1. Tankage	
a. Above ground, uninsulated, warm climates only.	Use Slide 179.2/12.1.8 Slide 179.2/12.1.8 is a photograph of an anaerobic digester under construction. The digester is exposed and is a fixed cover digester. The digester is constructed in a warm climate where insulation is not required.
b. More typical is below ground, insulated tankage 1) Fixed cover 2) Gas exit line 3) Pressure/vacuum relief valve 4) Flame arrester	Use Slide 179.2/12.1.9 Slide 179.2/12.1.9 is a photograph which shows the top of a fixed cover anaerobic digester. The digester is insulated by subsurface construction. The digester extends 32 feet below ground level. The fixed cover shows the gas removal line, the pressure release valve, the flame arrester.
c. High construction cost of tankage is one factor which tends to make anaerobic digestion economically unattractive.	
2. Raw sludge feeding system	
a. Pump raw sludge according to a regular schedule	
b. Sludge should not be too thick or too thin - approximately 5 - 8% for raw primary sludge, 1 - 2% for waste activated sludge and 3 - 5% for combined sludge.	
3. Gas collection and storage system	
a. Must provide airtight seal to maintain anaerobic conditions.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. Must provide storage space for gas.	
c. Must distribute gas to point of use or dispose of it.	
d. Three types of digester covers 1) Fixed covers 2) Floating covers 3) Gas holder covers	Use Slide 179.2/12.1.10 Slide 179.2/12.1.10 is a schematic diagram showing a fixed cover, floating and gas holder cover digester.
e. Units in gas handling/distribution. 1) Pressure relief valve 2) Vacuum relief valve 3) Sediment and driptrap 4) Flame trap 5) Pressure regulator 6) Check valve	Use Slide 179.2/12.1.11 Slide 179.2/12.1.11 is a photograph which shows the top of a fixed cover anaerobic digester which includes the complex arrangements for power to internal mixers below the enclosed box on the left, vacuum relief and flame arrester in front of the box, gas outlet piping, access manholes, and supernating box in the right background. A few other items are not visible such as sample holes, level indicators, etc.
4. Mixing system. Purpose is to prevent layering and keep the sludge well-mixed with even temperature.	
a. Types of mixing systems 1) Gas recirculation 2) Internal moving mixer 3) Liquid recirculation	
b. Operators must be provided with adequate digester mixing capacity - sufficient to recycle digester volume at least once a day.	Use Slide 179.2/12.1.12 Slide 179.2/12.1.12 is a photograph of an above surface anaerobic digester. The digester has a floating cover. The skewed piping, high and to the left, was installed for gas

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	recirculation. The gas recirculation mixing was not adequate. The "his" on the top box went with a "hers" on an adjacent digester not shown. This was for public relations because a yacht basin was located just outside the plant grounds and a large condominium complex was located within 300 feet of the plant. This operation had to be good and was.
	Use Slide 179.2/12.1.13 Slide 179.2/12.1.13 shows the 4" centrifugal pump which was installed by the operator of the digester shown in the previous slide to provide supplemental mixing and recirculation to compensate for the inadequate gas mixing system.
5. Heating system a. Used to maintain internal temperature at approximately 95°F. b. Keeping the temperature constant is even more important than the actual temperature of the digester. Of course, the digester must be in the proper range. 1) Best mesophilic range: 86-95°F 2) Temperature limits: 77-104°F c. Types of heating systems 1) Internal heat exchanger 2) External heat exchanger	Use Slide 179.2/12.1.14 Slide 179.2/12.1.14 is a photograph showing the boiler of a heated digester. The photograph shows two gas inlet lines, one for using digester gas and the other to provide supplemental natural gas.
6. Sludge and supernatant withdrawal systems	Use Slide 179.2/12.1.15 Slide 179.2/12.1.15 is a photograph showing an above surface digester with the supernate distribution box on

a. Supernatant is often withdrawn as raw sludge is being fed or just before raw sludge is fed.

b. Remove supernatant from level that gives best quality liquid for recycle back through plant.

c. Digested sludge is not withdrawn as often as the supernatant; will vary from daily withdrawal to monthly intervals or longer.

d. Sludge withdrawal should be planned so sludge build-up is not inhibiting digestion.

e. Operator should always keep about 20 times as much digested "seed sludge" as feed sludge to make certain that bacterial population is not reduced too greatly.

F. Environmental Requirements

1. The requirements of methane bacteria are much stricter than those required for acid forming bacteria.

2. Changes in environmental conditions will probably stop the action of the methane formers first.

3. General environmental conditions:

Parameter	Optimum	Limits
pH	6.8-7.2	6.4-7.2
Temp (^{o}F)		
Mesophilic	86-95	77-104
Thermophilic	122-131	113-140
Volatile Acids, mg/l	50-500	less than 2000
Alkalinity, mg/l	1500-3000	1000-5000
Vol Acids/Alkalinity	0.1-0.2	less than 0.5
Free DO, mg/l	-	-
Solids Feed, %	3-8% Primary 1-2% WAS 3-5% Mixed	

the upper left. This digester was designed for gravity discharge of digested sludge to ground level drying beds. The digested sludge would not flow by gravity through the installed line. The operator in this case attempted to unplug the line by blowing air into the digester. This situation is a no-no and creates an extremely explosive environment in making the digester a potential bomb.

Use Slide 179.2/12.1.16

Slide 179.2/12.1.16 is a word slide which repeats the detailed information on general environmental conditions for anaerobic digester operations. The data contained in the slide is shown in paragraph F.3 on the left.

LESSON OUTLINE

4. Toxic Materials

Toxic Materials	Conc, mg/l causing toxicity
Sodium	5000-8000
Potasium	4000-10,000
Calcium	2000-6000
Magnesium	1200-3500
Ammonia	1500-3000
Sulfide, soluble	200
Heavy Metals (ex) Copper, Zinc Lead, Nickel	Concentration depends on the sulfide concentration

a. Total heavy metals concentration seems to be more important than concentration of any single heavy metal.

b. Digester can acclimate to fairly high heavy metals concentrations.

c. Sludges tend to accumulate heavy metals in the digester.

d. Other materials toxic to the digester:

1) Phenols and plastic resins

2) Cyanide

3) Insecticides

4) Fungicides

G. Normal Digester Operations

1. Feed sludge continuously

2. Monitor key parameters

3. Record sludge input, withdrawal

4. Monitor gas production

5. Compute solids input, output

6. Check temperature profile periodically

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/12.1.17

Slide 179.2/12.1.17 is a word slide which lists toxic materials and toxic level concentrations in digesters. The content of the slide is the same as shown in paragraph F.4 on the left.

Use Slide 179.2/12.1.18

Slide 179.2/12.1.18 is a word slide which reads:

"Routine Digester Operations

Continuous Feeding of Sludge
Monitor Key Parameters
Record Sludge Input, Withdrawal
Monitor Gas Production
Compute Solids Input, Output
Check Temperature Profile Periodically

LESSON OUTLINE

7. Measure sludge level, temperature, digester pressure, cover height

8. Measure grit levels to know actual digestion volume available

H. Relationship of Digester Control Parameters During a Digester Failure

1. The top graph shows a digester operating with a good buffering capacity (the low volatile acids 200 mg/l compared to an alkalinity of 2,000 mg/l. At Point T_1 something has happened to cause the volatile acids to increase followed by a decrease in alkalinity at Point T_2. At Point T_3 the digester has become sour.

   a. Alert to possible problem when volatile acids reach 400 mg/l.

   b. Begin corrective actions when volatile acids reach 600 mg/l.

   c. When volatile acids reach 800-1000 mg/l may have lost the digester.

   d. Values given are typical. Digesters have their own personalities and each has unique parameter values corresponding to optimum operation for that digester.

2. The second graph continues the same digester performance by showing the volatile acids/alkalinity ratio. Notice that at Point T2, the increase in volatile acids produces an increase in the ratio from 0.1 to 0.3.

   a. Note that a VA/ALK change occurs as either the VA or alkalinity concentrations change.

KEY POINTS & INSTRUCTOR GUIDE

Measure Sludge Level, Temperature, Digester Pressure and Cover Height"

Use Slide 179.2/12.1.19

Slide 179.2/12.1.19 shows four graphs of digester operating parameters as a function of time. Parameters plotted are:

Upper graph - alkalinity and volatile acids
Second graph - volatile acids/alkalinity ratio
Third graph - percent methane and percent carbon dioxide
Fourth graph - pH

The graphs depict a digester failure beginning at time T1 with volatile acids increasing while alkalinity remains relatively constant. The graph plots the time relationships in which changes in other parameters would be observed as indicators of digester failure.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

b. VA/ALK ratio is probably the most sensitive control parameter.

c. Normal range of VA/ALK ratio is 0.1 - 0.2.

d. VA/ALK ratio increases to greater than 0.2, suspect possible problem.

e. VA/ALK ratio reaches 0.4, its time to start corrective action.

f. VA/ALK ratio greater than 0.5 means there's a good chance of losing the digester.

g. Each digester has its own optimum range for VA/ALK ratio.

3. By comparing % CH_4 graph with VA/ALK graph, methane production begins to drop with a corresponding increase in CO_2 when the VA/ALK ratio reaches about 0.5.

   a. Note that changes in VA, ALK and VA/ALK ratio lead the loss of gas production.

4. pH doesn't change in this graph until the digester is becoming sour at Time T_3 and the VA/ALK ratio begins to approach 1.

   a. pH is probably the most commonly measured digester control parameter.

   b. pH doesn't change until the digester is lost.

   c. pH is probably the poorest of the process control parameters.

5. Recommend that digester control be based on the VA/ALK ratio as the preferred indicator of digester condition and potential problems.

LESSON OUTLINE

I. Start-Up of Digesters

1. No seed available - single digester

   a. Fill digester with raw sludge and sewage to a level that will cause a seal to be formed around the cover (in a fixed cover system, fill to the overflow level). This is the operating level.

   b. When the tank is full, begin heating to bring contents to about 95°F as quickly as possible.

   c. Begin mixing and/or recirculating at maximum rate when operating level is reached.

   d. Begin feeding raw sludge at an even rate. Add gradually over 24 hour period.

   e. Maintain records and graph the following:

      1) Quantity of raw sludge fed

      2) Raw sludge, total and volatile solids

      3) Digester contents, TS, TVS

      4) Volatile Acids, Alkalinity, pH

      5) Temperature, Gas production, CO_2 content of gas

   f. Determine whether pH control will be required.

      1) At low feed rates, pH control may not be needed.

      2) If the VA/ALK ratio rises to

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/12.1.20

Slide 179.2/12.1.20 is a word slide which reads:

"Digester Start-Up

1. Fill with Raw Sewage
2. Heat to Desired Temperature
3. Mix and/or Recirculate
4. Feed Sludge
5. Monitor Digester Parameters
6. pH Control Needed
7. Continue Feed Until Fully Loaded and Stable"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
0.8 or more and pH is below 6.5, raise pH with lime or soda ash.	
g. Fairly stable conditions should be reached in 30-40 days if loadings do not exceed 0.06 #VS/day/ft^3.	
2. Seed available - single digester	
a. Determine the amount of seed sludge to be used. The amount of seed required is about 20 times the expected VS in the raw sludge	
b. Haul seed sludge and transfer into digester, fill tank with sewage.	
c. Follow steps I.1.b through I.1.f	
d. No chemicals should be needed if the raw sludge is fed evenly. If buffering is needed, sludge might be replaced with fresh seed.	See preceding paragraph
e. Fairly stable conditions should be reached in 1-2 weeks.	
3. Two stage digester - no seed available	
a. Follow procedure outlined in Step #1 with these exceptions:	
b. Fill both tanks with raw sewage	
c. Raw sludge may be fed into the primary with the supernatant flowing over into the secondary.	
d. The secondary may be used to keep the loading to the primary low - less than 0.06 #VS/cu ft/day.	

LESSON OUTLINE

4. Two-stage digesters - seed available

   a. Follow procedure outlined in Step #2 with these exceptions:

   b. Fill both tanks with sewage.

   c. Use secondary tanks to distribute loading and maintain loading less than 0.06 #VS/cu ft/day

III. Operational Problems in Anaerobic Digesters (25 minutes)

A. Principal Operating Problems in Anaerobic Digesters

1. No gas production
2. Scum blanket in tank
3. Increase in VA/ALK ratio
4. Foam in digester
5. Low reduction in volatile solids
6. High supernatant solids concentration

B. Have trainees refer to pp. 304-315 of *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*.

1. Identifying problems
2. Monitoring and inspecting
3. Correcting operational problems

Advise students to look over this material in detail. There will be opportunity later to use this information in troubleshooting exercises.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/12.1.21

Slide 179.2/12.1.21 is a word slide which reads

"Principal Operating Problems in Anaerobic Digesters

No Gas Production
Scum Blanket in Tank
Increase in Ratio of Acid to Alkalinity
Foam in Digester
Low Reduction of Volatile Solids
High Supernatant Solids Concentration"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
C. Visual Indicators of Anaerobic Digester Problems	
Instructor can follow slide key or may substitute personal slides that depict anaerobic digester problems. Emphasize operational aspects of digesters and evidence of poor operation in the pictures.	Guide: Try to have students identify problems shown by the slides. Instructor should ask, "Can you see anything here that would cause the operator problems?" or "What problems do you see here?", etc. Use slides to encourage class input.
1. Waste Gas Burner a. Blue to faint yellow flame with blue at base - normal b. Orange flame with smoke - high sulfur c. Yellow color - poor quality gas, high CO_2, suspect organic overload d. No flame, rancid butter odor - suspect toxics!	Use Slide 179.2/12.1.22 ~~Slide 179.2/12.1.22~~ is a photograph showing the waste gas burner on top of a digester. The flame is barely visible indicating good digester performance producing a good quality gas.
2. Sniff Tests a. By smelling sludge samples, operators can tell whether digester is septic, sour, well-digested or has had an industrial dump. b. "Rotten egg odor" - organic overload c. "Rancid butter odor" - butyric acid phase. Digester lost. Start over. May be a heavy metals or other toxicity problem.	
3. The viewer is correct. This floating cover isn't level.	Use Slide 179.2/12.1.23 ~~Slide 179.2/12.1.23~~ is a photograph of a floating cover digester with the floating cover tilted.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
4. A common occurrence when the cover isn't level is represented here on another digester. The gas is bubbling through the water seal on the tilted cover and spattering solids over the top. This one was a deliberate tilt because	Use Slide 179.2/12.1.24 Slide 179.2/12.1.24 is a photograph of the top of a floating cover digester showing scum and foam rising from the space between the floating cover and the digester wall. The foam results from a break in the water seal because of excess gas accumulation allowing the foam to escape from the digester.
5. The gas line from the digesters to the gas holder about 1,000 feet away had corroded and wasn't repaired. The gas went into the air because of the lack of usable pipe line. It is not understood why the designer positioned the producer and storage units quite so far apart, but unfortuantely, it isn't that unusual.	Use Slide 179.2/12.1.25 Slide 179.2/12.1.25 is a photograph taken from the top of the digester shown in the previous slide. This shows the gas storage tank located approximately 1,000 feet from the digester. The line between the digester and the gas storage tank had corroded and broken. One questions why the gas storage facility was placed so far from the gas producer, the digester.
6. Supernatant returns do not have to be a troublesome return flow problem. This series of 3-500 gallon tanks took care of supernatant treatment for a 1.6 MGD plant. At first, one tank was being filled, one tank for dosing with about 250 mg alum - Al/liter and mixed while the third was settled. The clarified liquid returned to process and the solids concentrate pumped to disposal. These tanks were later converted to a flow through operation. The slide shows two of the three tanks.	Use Slide 179.2/12.1.26 Slide 179.2/12.1.26 is a photograph of two 500-gallon chemical precipitation tanks which were used to treat digester supernate prior to recycling to the system. Alum was added to precipitate phosphorous, floccuate suspended solids, reducing solids, phosphorous and BOD recycled back to the system. Refer class to page 303 of *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* for supernate characteristics.
7. You won't often see 2 x 2 x 3 foot concrete blocks at about 15 feet center to center spacing to hold a digester floating cover down. It did, as you see from the sludge residues on	Use Slide 179.2/12.1.27 Slide 179.2/12.1.27 is a photograph of a top of a floating cover digester on which have been placed large concrete blocks at about 15' intervals.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
the blocks.	The blocks were used to weight the cover down and prevent it from floating.
8. This is the same cover showing sludge drying bed area almost completely covering the "floating" cover. This plant had been in operation slightly over two years. It was a complete secondary plant including vacuum filtration and incineration. One maintenance man and two operators were on board where 17 had been recommended. The operating requirements called for a discharge limit of about 111 BOD_5 and 140 mg SS/liter. It didn't take much operation to meet the limit. There had been no sludge disposal. Everything was full, which again is not uncommon, but certainly not desirable.	Use Slide 179.2/12.1.28 Slide 179.2/12.1.28 is a photograph of the top of the weighted floating cover digester showing accumulation of dried sludge solids on the surface. Operators had not wasted sludge since the plant started up because they received odor complaints when they pumped inadequately stabilized solids to the drying beds during start-up. The discharge limit on this plant was 111 BOD_5 and 140 mg SS/l. Because of solids accumulation throughout the system, the limit couldn't be met.
	Guide: Following the slides, the instructor should call for comments and questions before going on to the next section.
D. Troubleshooting Anaerobic Digesters (25 minutes)	
For a good overall presentation of the operations of anaerobic digesters, including troubleshooting, the instructor should refer the class to "Operations Manual - Anaerobic Sludge Digestion" by Zickefoose, STRAAM, Inc, for EPA, February, 1976.	Listed in References section of *Trainee Notebook*.
1. Using the Process of Troubleshooting for Problems with Anaerobic Digesters	Refer trainees to troubleshooting chart and
a. Troubleshooting anaerobic digestion	Use Slide 179.2/12.1.29 Slide 179.2/12.1.29 is a word slide which reads: .
1) Review plant information at office	
2) List potential problem areas	"Troubleshooting Anaerobic Digester- Initial Plant Visit Activities

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3) Visit plant	Talk to Operator Get Background on Plans Study Piping, Pumping, Heating Analyze Process Controls Find Out What Operator Has Been Doing"
a) Talk with operators	
b) Study piping, valves, etc.	
c) Analyze process controls	
d) Review operating data for 30 days	
e) Find out what operators have been doing (does it differ from reported data?)	
4) Determine further data needs	
5) Formulate and test alternatives	
6) Take corrective action	
7) Observe and test	
8) Implement long-range action	
b. Evaluate normal process monitoring for anaerobic digestion	Use Slide 179.2/12.1.30 Slide 179.2/12.1.30 is a word slide which reads: "Normal Process Monitoring - Anaerobic Digestion Daily: pH, Temperature, Gas Production Weekly: Alkalinity, Volatile Solids, Fixed Solids, Volatile Acids Note: Operators may approximate solids by using solids settleability and spin tests.
1) Visual inspections (waste gas burner)	
2) Smells	
3) Solids levels, input and output	
a) Total solids	
b) Volatile solids	
c) Fixed solids	
4) Volatile acids/alkalinity	
5) pH (Usually not best check)	
6) CO_2 levels and gas production	

LESSON OUTLINE

c. Look for clues to check validity of test results

Troubleshooting Clues

1) Unusual operating procedures
2) Monitoring parameters - unusual results
3) Unusual staff behavior
4) Suspicious records
5) Other???

2. Factors Used in Digester Evaluation

a. Gas production

1) Unheated digester
   0.32 - 0.56 ft^3/capita/day
2) Heated digester
   0.56 - 0.74 ft^3/capita/day

b. Solids loading

1) Low rate
   Less than 0.1 #VS/ft^3/day
2) High rate
   0.15 - 0.2 #VS/ft^3/day

c. Hydraulic detention time

1) Low rate: 30 - 60 days
2) High rate: 10 - 30 days

d. Rate of feed and withdrawal

1) Feed continuously is best
2) Feed small amounts frequently if continuous is not possible

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/12.1.31

Slide 179.2/12.1.31 is a word slide which reads:

"Troubleshooting Clues

Unusual Operating Procedures
Monitoring Parameters - Unusual Results
Unusual Staff Behavior
Suspicious Records
Other???"

Use Slide 179.2/12.1.32

Slide 179.2/12.1.32 is a word slide which reads:

"Factors for Process Evaluation - Anaerobic Digester

Gas Production - Actual vs. Computed
Solids Loading (Volatile Matter)- 0.05 - 0.2 lbs/cu ft/day
Hydraulic Detention Time - 10 - 30 days
Rate of Feed and Withdrawal"

Note: Depending on sludge characteristics and other digester conditions, some high rate systems may be operated at loading approaching 0.4 #VS/ft^3/day.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. Compare to Expected Results a. Alkalinity: 2500 mg/l b. Volatile Acids: less than 800 mg/l c. Gas: 60-70% CH_4, 30-40% CO_2 d. Raw Sludge: 3-8% Solids, 70-80% volatile e. pH: 6.8-7.2 f. Volatile Matter Reduction: 50-80%	Use Slide 179.2/12.1.33 Slide 179.2/12.1.33 is a word slide which reads: "Expected Analytical Results Alkalinity: 2500 mg/l Volatile Acids: less than 800 mg/l Gas: 30-40% CO_2 Raw Sewage: 3 - 8% solids, 70-80% volatile ph: 6.8 - 7.2 Volatile Matter Reduction: 50 - 80% "
E. Use any remaining time for questions and answers.	Use Slide 179.2/12.1.34 Slide 179.2/12.1.34 is a blank.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 12: Solids Handling

Lesson 1: Anaerobic Digestion

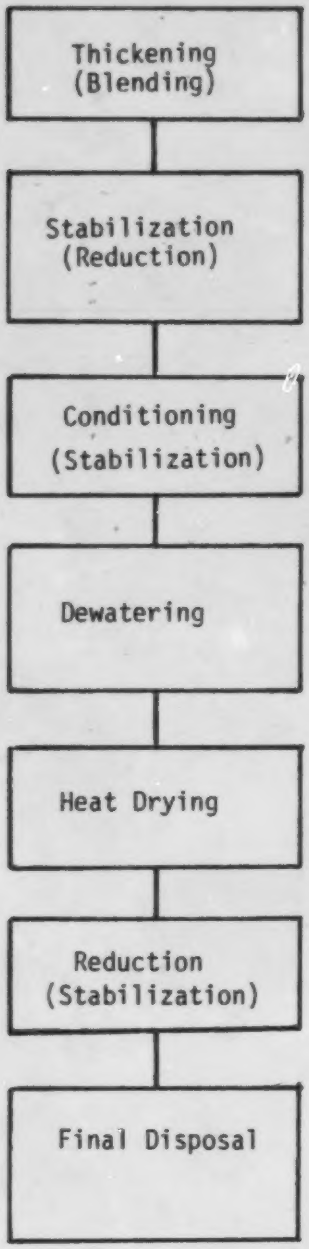
Trainee Notebook Contents

Sludge Treatment Processes T12.1.1

Unit Processes - Sludge Processing and Disposal T12.1.2

Standard Rate and High Rate Digestion T12.1.3

Start-Up Procedures for Digesters T12.1.4

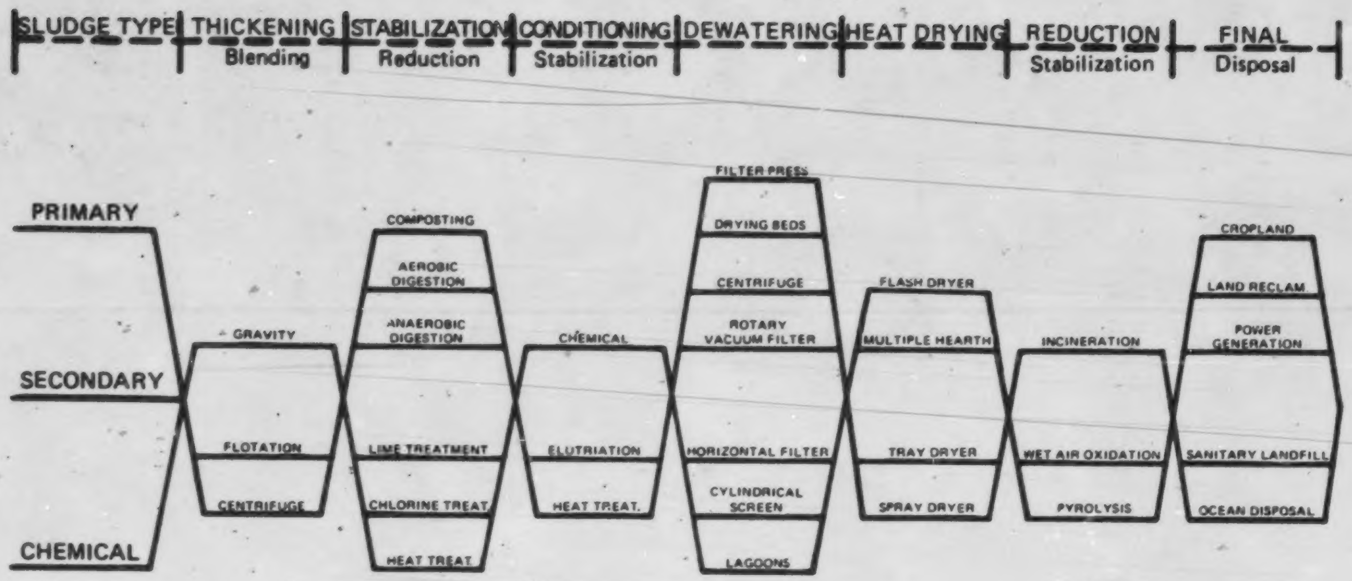


UNIT PROCESSES	FUNCTIONS
Thickening (Blending)	- Water Removal - Volume Reduction - Post Process Efficiencies - Blending
Stabilization (Reduction)	- Pathogen Destruction - Volume and Weight Reduction - Odor Control - Putrescibility Control - Gas Production
Conditioning (Stabilization)	- Improve Dewatering or Thickening Rate - Improve Solids Capture - Improve Compactability - Stabilization
Dewatering	- Water Removal - Volume and Weight Reduction - Change to Damp Cake - Reduces Fuel Requirements for Incineration/Drying
Heat Drying	- Water Removal - Sterilization - Utilization
Reduction (Stabilization)	- Destruction of Solids - Water Removal - Conversion - Sterilization
Final Disposal	- Utilization (Cropland) - Utilization (Energy) - Utilization (Land Reclamation) - Disposal (Landfill) - Disposal (Ocean)

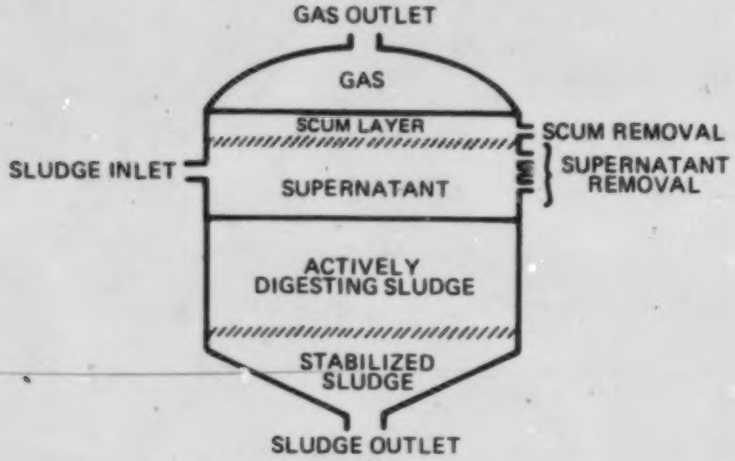
Sludge Treatment Processes

UNIT PROCESSES - SLUDGE PROCESSING AND DISPOSAL

T12.1.2



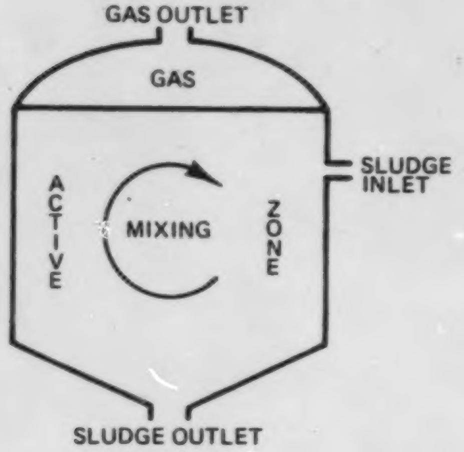
Reproduced from EPA Manual "Sludge Treatment and Disposal"



(A)

STANDARD RATE DIGESTION

1. UNHEATED
2. DETENTION TIME 30 – 60 DAYS
3. LOADING 0.03 – 0.10 lb. VSS/cu. ft./day
4. INTERMITTENT FEEDING AND WITHDRAWAL
5. STRATIFICATION



(B)

HIGH RATE DIGESTION

1. HEATED TO 85° – 95° F
2. DETENTION TIME 15 DAYS OR LESS
3. LOADING 0.10 – 0.50 lb. VSS/cu. ft./day
4. CONTINUOUS OR INTERMITTENT FEEDING AND WITHDRAWAL
5. HOMOGENEITY

STANDARD RATE AND HIGH RATE DIGESTION

Start-Up Procedures for Digesters

1. Fill with raw sewage
2. Heat to desired temperature (approximately 95°F).
3. Feed digester at 0.01 lb of VM/ft^3/day.
4. Compute volatile acids, alkalinity and pH daily.
5. Buffer the system with lime or sodium bicarbonate.
6. Plot volatile acid and alkalinity concentration and VA/ALK ratio as a function of time.
7. Mix digester continuously if possible and maintain constant temperature.
8. As soon as volatile acid concentration starts to drop, increase loading by 0.01 lbs of VM/ft^3/day.
9. Continue until full load is on system.
10. Seed sludge can be added to accelerate the start-up process provided it can be added in sufficient quantity (10% of tank volume) and not be cooled or aerated in the transfer process.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 12: Solids Handling

Lesson 2: Problem Solving in Anaerobic Digestion

Lesson 2 of 5 lessons Recommended Time: 110 minutes

Purpose: This lesson requires the trainees to practice applying the process of troubleshooting to anaerobic digestion problems using a role playing simulation exercise. Three trainees from each four person work group role play troubleshooters while the fourth member of the work group role plays the operator. The exercise is conducted using a "fish bowl" technique in which a second four person work group observes the role playing exercise and then critiques the performance of the troubleshooters. Two problems are solved so that each work group participates in both observer and troubleshooter roles. The thrust of the exercise is to emphasize the importance of oral communication and attitude in troubleshooting. In this exercise proper application of the process of troubleshooting and interpersonal communication skills are more important than is solution of the technical problems provided.

Trainee Entry Level Behavior: Trainees should have achieved the learning objectives specified for Unit 12, Lesson 1 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson the trainee will be able to:

1. Demonstrate proper troubleshooter behavior and apply the process of troubleshooting in an oral interview role playing exercise.

2. Explain the importance of proper troubleshooter behavior by observing and constructively critiquing other trainees' performances during a role playing troubleshooting exercise.

3. Demonstrate his/her ability to organize and conduct an oral interview to obtain essential technical data for troubleshooting an anaerobic digester problem and recognize how the interview technique must be adapted to respond to the personality and attitude of the plant operator.

4. Demonstrate his/her understanding of anaerobic digester operations and troubleshooting by successfully solving the problems presented.

Instructional Approach: Trainee problem solving in a role playing exercise using the "fishbowl" technique.

Fishbowl Technique. The approach to this lesson subdivision employs two educational techniques that allow the trainees to participate in and experience the process of troubleshooting.

1. One technique is "role playing." For each problem, a four-person group is assigned, with one person playing the role of the operator - with specific instructions, and the other three persons playing the role of troubleshooters.

The second technique is the "fishbowl" technique, where one group observes the other group carrying out the role playing exercise in attempting to solve the assigned problem. The observing group should take notes on what they see and report back at the appropriate time.

The group involved in "role playing" to solve the assigned problem is known as the "inner group" (inside the fishbowl) and is seated accordingly. The group of observers is known as the "outer group."

Groups for this lesson subdivision must be pre-designated by the instructor and should be as balanced as possible in composition so that all groups are roughly comparable.

2. The individual selected to play the role of "plant operator" from each group should be a person who is relatively experienced in the inspection of treatment plants compared to his/her fellow trainees. The selected individuals should also be chosen from among those who have personalities which would make them not reticent to participate. The individuals who are to be "plant operators" should be pre-selected and given their instructions in advance of this lesson subdivision.

3. It is very important that the observers be encouraged to give honest feedback to the troubleshooters - after the 20 minute troubleshooting experience is completed. It is this feedback that provides much of the learning experience for this lesson.

4. After one problem has been analyzed and feedback provided, the groups must switch so that the "inner" and "outer" groups change places. A new "operator" and new troubleshooters then address the second problem with the new observers taking notes.

5. After both problems have been analyzed and feedback is reported by the observers, it is important for the instructor to bring the entire class together to discuss the results and for the trainees to discuss their role playing experiences. This overall comparison of what occurred in each group is an essential conclusion to this exercise that allows the trainees to compare notes and obtain an overall impression of the troubleshooter-operator relationship.

6. Some trainees may be very timid in their role playing involvement. In trial presentations, a very small percentage (1%) were very negative and even belligerent. The instructor must "cruise" from group to group to see that people participate and to encourage them to do so. However, if a trainee's attitude is so negative as to disrupt the others, he/she should be excused from this portion of the lesson.

Details on administering the lesson are provided in the lesson plan outline.

Lesson Schedule: The 110 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 10 minutes	Instructor Introduces the Lesson, Sets up Groups, Provides Instructions
10 - 30 minutes	Groups Plan their Approach to the Problem
30 - 50 minutes	Designated Groups Analyze and Troubleshoot Problem 1
50 - 60 minutes	Observers for Problem 1 Report Findings
60 - 80 minutes	Designated Groups Analyze and Troubleshoot Problem 2
80 - 90 minutes	Observers for Problem 2 Report Findings
90 - 110 minutes	Entire Class Convenes to Discuss Findings and Experiences with the Instructor

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T12.2.1, "Instructions to Troubleshooters: Problem 1.
2. *Trainee Notebook*, pages T12.2.2, "Instructions to Troubleshooters: Problem 2.
3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Plants*, pages 295-315.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 12.2.1 - 12.2.11, Unit 12, Lesson 2.
2. *Instructor Notebook*, pages H12.2.1 - H12.2.2 , "Instructions to Operators: Problem 1."
3. *Instructor Notebook*, pages H12.2.3 - H12.2.5 , "Instructions to Operators: Problem 2."

Instructor Materials Recommended for Development: None

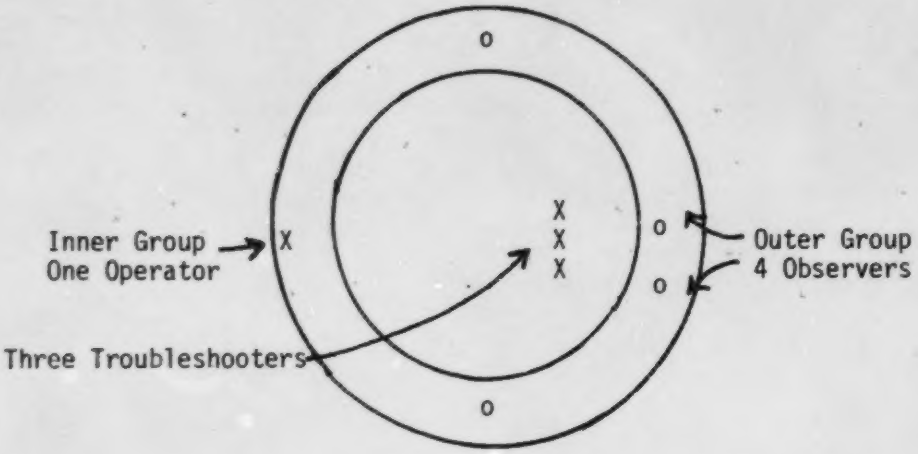
Additional Instructor References: None

Classroom Set-Up: The classroom should be set up to accommodate groups of eight (8) trainees. If possible, to avoid distraction from one group to another, separate rooms should be used for each group of 8.

Each group of 8 consists of two (2) four-person groups, an "inner" group who are actually participating in the role playing-problem solving and an "outer" group who are observing.

Each "inner" group consists of three (3) troubleshooters and one (1) trainee who is playing the operator's role.

Each group of 8 should be arranged as in this diagram.



LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Prior to Start of Lesson	
A. Trainee groups should be designated by Course Director or instructor.	Guide: Instructions for operator are available as part of *Instructors Notebook*, pages H12.2.1 - H12.2.5 They must be reproduced prior to the lesson.
B. Instructor should choose one member of each group to play the role of "operator."	
1. Distribute "Instructions to Operating Personnel" to persons selected as operators.	Instructions for troubleshooters are included in the *Trainee Notebook*, pages T12.2.1 - T12.2.2
II. Introduction (10 minutes)	
A. Introduce lesson	Refer to the "Instruction Approach" section of the lesson plan for detailed discussion of the approach.
B. Announce group composition	Pairing Group 1 with Group 2, Group 3 with Group 4, etc., is probably the easiest approach. Odd numbered groups solve problem 1 and even numbered groups solve problem 2.
C. Select groups to be "inner" or "outer" groups.	
D. Emphasize to trainees playing the role of troubleshooters that they should:	
1. Work as a team in questioning the "operator."	
2. Use the "Process of Troubleshooting," i.e., be analytical.	
3. Find the answer and solve the operator's problem in 20 minutes.	
E. Emphasize to the "outer" group of observers to take notes and be prepared to comment on how well the troubleshooters perform.	
F. Privately emphasize to the trainees acting as operators for Problem 1 that they are to be *cooperative but inexperienced*. In response to any question that is not covered in the operator's instruction sheet they are to indicate that they don't	Use the 20 minutes allocated for preparation below to brief the "operators" while the troubleshooters plan their approach.

LESSON OUTLINE

know the answer. If the troubleshooters give detailed instructions on how to obtain the answer, the operator will agree to get the answer and call the troubleshooter back tomorrow.

Privately emphasize to the students acting as operators for Problem 2 that they are to be *reluctant and defensive to the point of thinly veiled hostility*. In response to any question that is not covered in the operator's instruction sheet, they are to indicate that they don't know the answer. If the troubleshooters ask for additional information or data, the operator cannot, will not or does not have time to furnish it.

G. Have student groups go to their assigned places.

III. Preparation (20 minutes)

A. Allow troubleshooting groups and operators 20 minutes to prepare their approaches to Problem 1.

IV. Problem 1 (20 minutes)

A. Instructor should make sure "inner" and "outer" groups go to their respective seats.

B. Instructor should "cruise" from group to group to oversee the exercise.

C. Call time after 20 minutes.

V. Feedback for Problem 1 (10 minutes)

A. Observers should report their findings on how the troubleshooters performed.

B. After 10 minutes, have groups switch places for Problem 2.

KEY POINTS & INSTRUCTOR GUIDE

Use this time to brief "operators"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
VI. Problem 2 (20 minutes)	
A. Instructor should make sure "inner" and "outer" groups go to their respective seats.	
B. Instructor should "cruise" from group to group to oversee the exercise.	
C. Call time after 20 minutes.	
VII. Feedback for Problem 2 (10 minutes)	
A. Observers should report their findings on how the troubleshooters performed.	
B. After 10 minutes, bring the entire class back together to review the problems, the observations and the results of the exercise.	
VIII. Discussion of Findings and Results (20 minutes)	
A. Brief review of results of the troubleshooting problems.	Key Point: The instructor should cover the technical solutions as quickly as possible. Focus discussion on the observed behavior of the troubleshooters and operators.
1. Problem 1 If the troubleshooters follow proper troubleshooting techniques, the most obvious cause should become apparent.	Emphasize: 1. The importance of a systematic approach 2. That the technique can be used by people other than operations consultants a. Senior operators b. Department heads c. Regulatory personnel
The digester is organically and hydraulically overloaded because the weekend operator pumped down the out of service primary clarifier as quickly as possible. The operator should reduce or cease pumping raw sludge to the digester.	Clues: 1. Rapid temperature drop indicates increased hydraulic load to digester. 2. Foaming and froathing characteristic of organic overload. 3. "Rotten egg" odor is typical of organic overload problems.

LESSON OUTLINE

He should add lime to raise the pH and continuously recirculate the digester contents via the heat exchanger to gradually raise the temperature to 95°F.

The troubleshooter should have the operator start the corrective program immediately and then assure the operator that a continual follow-up will be implemented to confirm and assist.

2. Problem 2

If the troubleshooters follow proper troubleshooting procedures, the problem and its cause can be determined.

The digesters have received a slug of toxic material, maybe heavy metals. The operator should isolate and hold the waste if possible. (He tried to do this.) If not, the operator should reduce mixing to minimize contact of the toxic sludge with the entire digester contents.

KEY POINTS & INSTRUCTOR GUIDE

Feeding Lime:

1. Must slurry lime before feeding.
2. Can estimate lime dose by drawing a five gallon sample of digester contents and adding lime to sample while monitoring the pH. Can then estimate the total pounds of lime needed to increase the digester pH.
3. Feed about half the total lime dose the first day. Wait a day and monitor pH. Add more lime as needed on following days to avoid overdosing the digester.

Clues:

1. Sudden loss of gas production and rapid drop in pH indicates possible toxicity.
2. "Rancid butter" odor of digested sludge indicates presence of butyric acid. The methane formers have been killed. This is characteristic of toxic effects. "Rotten egg" odor is characteristic of organic overload.
3. Operator was treating the dairy waste problem which he had before but the treatment is not working this time.

LESSON OUTLINE

The final solution will depend on the type and amount of waste present. It may be possible to dilute the waste below toxic level using either seed sludge from another digester or water for the dilution.

Or you might:

1. Form an insoluble product. Remove soluble sulfides by adding iron salts causing iron sulfide to form. Remove heavy metals by adding sulfuric acid or a sulfide to cause formation of metal sulfides.

2. Use another compound that will react with the toxic compound to form less harmful compounds. To discover just what type of antagonistic element is needed, some careful work will be needed.

3. Empty the digesters and start all over again.

4. The best long-term solution is to implement a good industrial pretreatment system to make sure that this doesn't happen again.

KEY POINTS & INSTRUCTOR GUIDE

4. The "rotten egg" odor came from the raw sludge pumped to the drying beds. Lime the sludge on the beds to reduce odors and decomposition.
5. "Bulking" in the activated sludge units may be deflocculation caused by toxic load to the plant.

Note: This is especially true with cyanide and chromium wastes.

Have class discuss how one might implement a total digester dump if this is needed.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
B. Discuss with class whether or not the troubleshooters approached the problem by using the Process of Troubleshooting.	Key Points: Discuss these key points with the class and maximize class input.
C. What aspects of troubleshooter-operator behavior were observed in the exercise?	

Note on Distribution of Instructions

The following sets of instructions must be reproduced prior to this lesson and distributed to trainees for the lesson.

Distribution

"Instructions to Troubleshooters" go to each troubleshooter and each observer and are included in the *Trainee Notebook* as pages T12.2.1 and T12.2.2.

"Instructions to Operators" go only to trainees playing the role of "Operator" and to each observer. These are included in the *Instructor Notebook* as pages H12.2.1 -H12.2.5. Troubleshooters are not given the "Instructions to Operators" for the problem which they must troubleshoot.

Troubleshooters may be given copies of the "Instructions to Operators" after the problem has been completed.

The easiest way to handle distribution of the "Instructions to Operators" is to give the trainee who role plays the operator eight copies of the instructions. The operator can distribute copies to the "observers" as the problem solving exercise begins and copies to the "troubleshooters" when the exercise is completed.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 12: Solids Handling

Lesson 2: Problem Solving in Anaerobic Digestion

Trainee Notebook Contents

Instructions to Troubleshooters

Problem Number 1 . . . . T12.2.1

Problem Number 2 . . . . T12.2.2

Solids Handling

Problem Solving in Anaerobic Digestion

Instructions to Troubleshooters

Problem Number 1

You are an operations consultant with Acme Environmental Associates. It is early Monday morning and you receive a telephone call from an operator that is a client of your firm.

He reports that foam is being discharged from the upper level supernatent line and foam is visible through the sight glasses in the digester roof.

The plant is a 1 MGD trickling filter unit with a fixed cover anaerobic digester. The last time that you visited the plant was 6 months ago.

The operator is uncertified and has been on the job for about a year. He is cooperative but relatively inexperienced. He is concerned and asking for help.

You inform the operator that you expect to be in his vicinity later in the morning and will be traveling with some of the other field staff persons from your office, so you'll bring them along.

As you enter the plant you notice that the flame at the waste gas burner has an orange color. You detect a septic sewage "rotten egg" odor. You also notice that one of the two primary clarifiers is out of service.

When you arrive at the plant (after having reviewed all available records), you begin your troubleshooting procedures.

Solids Handling

Problem Solving in Anaerobic Digestion

Instructions to Troubleshooters

Problem Number 2

You are an operations consultant for Anderson Environmental Associates (AEA). You have just received a telephone call from an irate municipal official. He lives 600 yards downwind from a municipal wastewater treatment plant that your firm designed. He states that the plant smells terrible and that the odor is making him ill and the condition has existed for three days.

The official reminds you that AEA is on retainer to his city and demands that you remedy the situation immediately.

He has already complained twice to the treatment plant operator. The operator told the official that the odor wasn't his fault - he was doing all that he could, but he had a "damn poor" engineering design to work with. He suggested that the official talk with your firm since AEA designed and started up the plant about seven years ago.

Before calling the plant, you pull the file and study the situation. The plant is a 2 MGD activated sludge plant with two-stage anaerobic digesters. The plant serves a community of 12,000 people and several small industries. The industries consist of a poultry processing plant, a cheese and dairy products plant, a clothing manufacturer and a large metal office furniture manufacturing and finishing operation.

All monthly operating records that you could obtain show good operating results. You could find no operating records for the past 3 months however. The operator is certified under the grandfather clause and has over 25 years experience. The last AEA visit of the treatment plant site was about 7 months ago. The operator has never called AEA to ask for assistance, so you assumed that the operation was running smoothly.

You telephone the plant and offer to visit with the operator to assist in solving the odor problem. The operator says that he is too busy to be visiting with people because he's having digester problems and has had to dump sludge to the drying beds. He agrees to spend a few minutes with you but lets you know that he should be working on the digester problem and not wasting time with a bunch of "f---ing engineers."

It sounds like an interesting problem, so you decide to take along several work associates. As you enter the plant, you notice that there is no flame at the waste gas burner. As you near the plant, you detect a strong septic sewage "rotten egg" odor. The primary tanks which you pass look bad. They're black and black sludge is floating on the surface.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 12: Solids Handling

Lesson 2: Problem Solving in Anaerobic Digestion

Instructor Handout Contents

Instructions to Operating Personnel

Problem Number 1 . . . . H12.2.1

Problem Number 2 . . . . H12.2.3

Solids Handling

Problem Solving in Anaerobic Digestion

Instructions to Operating Personnel

Problem Number 1

1. You are the operator of a 1 MGD trickling filter plant with a single fixed cover, heated anaerobic digester.

2. You are an uncertified operator and, in addition to the wastewater treatment plant, you also operate the water plant, collection system and water distribution system. You're still on probation with your employer and are willing to do almost anything to solve the problem quickly and demonstrate your competence as an operator.

3. On Monday morning when you arrive at the plant, you discover foam being discharged from the upper level supernatant line and, when you investigate the cover, you see foam through the sight glass.

4. Your anaerobic digester is a fixed cover unit with no mechanical or gas mixing equipment. Total recirculation is possible and the unit is heated by an external heat exchanger. Recirculation through the heat exchanger provides the only mixing in the unit.

5. You immediately telephone your community's engineering firm and talk with their operations consultant who promised to stop by later today. The consultant has not been to your plant in 6 months.

6. In response to specific questions, you supply the following data. (If you knew what data were important and how to properly interpret the data, you would not have called for assistance.)

   a. Operating Data on the Digester

Parameter	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.	Mon.(today)
pH	?	7.0	7.0	7.0	7.0	-	-	6.6
Temperature, °F	?	95	95	95	95	-	-	92
Volatile Acids, mg/l	800	-	-	-	-	-	-	?
Alkalinity, mg/l	2700	-	-	-	-	-	-	?
Sludge Pumped to Digester		------No Records------						

b. You cannot perform solids analyses or gas analyses in your laboratory because you don't have the equipment for these tests.

c. Digester gas has a "rotten egg" odor but is still burnable. The waste gas burner flame is orange colored.

d. No sludge has been withdrawn from digester for over a month.

e. Nothing unusual occurred last week when you were on duty. The only thing that you can remember is that a flight chain broke on number one primary settling tank Friday.

f. You instructed the weekend operator to dewater number one primary settling tank on Saturday and Sunday so you could repair the chain Monday. The tank was empty when you came to work this morning.

g. There are no significant industries connected to the system.

h. Lime is available at the water plant.

7. Additional Data:

a. If the troubleshooters ask you to do so, you will run additional tests. You will run these tests only if asked to do so.

Additional Data for Monday

Volatile Acids, mg/l	1600
Alkalinity, mg/l	1800

b. If the troubleshooters suggest that you "lime" the digester, make sure that they tell you how to do it because you've never limed a digester before. How do you add the lime? How much do you add?

Instructions on Operator Behavior

You are a cooperative but inexperienced operator. If you receive any questions for which the answers are not provided in these instructions, indicate that you do not know the answer. If the troubleshooter gives instructions on how to obtain the answer, agree to try to get it and indicate that you will call him back tomorrow with the answer.

Solids Handling

Problem Solving in Anaerobic Digestion

Instructions to Operating Personnel

Problem Number 2

1. You are the operator of a 2 MGD activated sludge plant with two-stage anaerobic digesters.

2. You are certified under the grandfather clause because you have twenty-five years of experience and did not have to take a test designed by some young engineer.

3. The anaerobic digesters are floating cover units of equal size with gas mixing equipment and external heat exchangers. Digested sludge is dewatered on sludge drying beds.

4. For the past week you have been working twelve hours a day with two sick digesters and for the past three days people have been complaining and demanding that you do something. To top off your day, some engineer from AEA has decided to come over because of complaints by a city official.

5. The digesters were both full when you noticed the gas production and pH drop. The last time that happened the cheese plant had slugged the treatment plant. To cure the problem, you raised the pH with lime and rested the digesters. This is what you are doing now, except you had to fill two drying beds with sludge in order to have room to mix the lime. The beds and what little gas is being produced have a "rancid butter" odor.

6. You will answer questions from the troubleshooter but you will not offer any additional information.

   a. You have modified the digesters so that they operate as two single-stage complete mixing digesters. Both digesters are sick.

   b. pH: Today--6.1 on both digesters.
   Prior to failure: pH varied between 7.1 and 7.2 on both digesters.

   c. Volatile Acids: Today--4,000 mg/l
   Prior to failure: 400 mg/l on both digesters

   d. Alkalinity: Today--1,200 mg/l
   Prior to failure: 2,400 mg/l on both digesters

e. To date you have added 1,500 lbs of lime to each of the digesters and have succeeded in stopping the pH drop. The pH has not yet begun to increase.

f. The temperature in each unit is 95°F and it has remained constant.

g. Prior to the failure the gas mixing system was operated on a daily basis and scum is not a problem.

h. Total raw sludge solids content is between 6 and 8 percent.

i. Volatile solids content of sludge is approximately 60 percent.

j. The rate of feed to the digester has remained constant.

k. The digested sludge and what little gas is being produced does not have a "rotten egg" odor. The odor is similar to the smell of "rancid butter."

l. Since you have not been pumping raw sludge to the digesters at a normal rate, there is a sludge build-up in the primary settling tank. The sludge is becoming septic and floating to the top. You've had to pump some raw sludge to the drying beds and its beginning to smell.

m. The pH drop occurred overnight and the usable gas production ceased overnight.

n. Your grit collector works well and there is no large accumulation of grit in the digesters.

o. You have no laboratory capability to run exotic texts. The only tests you can run are those required to operate the plant and comply with NPDES reporting requirements.

p. To top things off, the activated sludge units started bulking about the same time the digesters failed. You're having trouble getting the activated sludge plant back in operation.

Instructions on Operator Behavior

You're getting near retirement and you don't really like other people meddling around your plant. You are reluctant to provide information and are defensive. You will answer specific questions reluctantly but you won't volunteer any information.

You think you can solve your problem without any help if people will leave you alone and let you do the job. You're upset because you're about to receive a 25 year award from the State Water Pollution Control Federation Chapter and you don't want this incident to spoil it.

You're upset with the city officials because they've asked the engineers to come help you solve this problem. Your attitude about engineers is negative because in your opinion you've never met one that knew anything about operations and very few that knew anything about designing wastewater treatment plants. You had some good ideas when the plant was being designed but AEA chose to ignore them all.

You want to get rid of these AEA people as quickly as possible and get back to work.

Unit of Instruction 12: Solids Handling

Lesson 3: Other Methods of Solids Handling

Lesson 3 of 5 lessons Recommended Time: 90 minutes

Purpose: Many methods in addition to anaerobic digestion are used in solids handling and conditioning. This lesson presents problem identification and troubleshooting information on gravity thickening, dissolved air flotation thickening, centrifugation, aerobic digestion, sludge drying beds and vacuum filtration. Heat treatment and incineration are not discussed in the course.

Trainee Entry Level Behavior: The trainee should have achieved the learning objectives specified for Unit 12, Lessons 1 and 2 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee should be able to:

1. From memory, describe and explain the purposes and functions of the following solids handling processes:
    a. Gravity thickening
    b. Dissolved air flotation thickening
    c. Centrifugation
    d. Aerobic digestion
    e. Sludge drying beds
    f. Vacuum filtration
2. Using references, list the operating parameters and their expected ranges for evaluating the operational performance of the solids handling unit processes and operations listed in Objective 1.
3. Using references, list common operational problems which occur with the solids handling unit processes and operations listed in Objective 1 and describe how each problem may be diagnosed and corrected.

Instructional Approach: Illustrated lecture with class discussion.

Lesson Schedule: The 90 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 10 minutes	Introduction
10 - 30 minutes	Aerobic Digestion
30 - 40 minutes	Sludge Drying Beds
40 - 50 minutes	Gravity Thickening
50 - 60 minutes	Dissolved Air Flotation Thickening
60 - 70 minutes	Vacuum Filtration
70 - 80 minutes	Centrifugation
80 - 90 minutes	Summary

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T12.3.1 - T12.3.4, "Typical Performance Characteristics of Solids Handling Systems."

2. *Trainee Notebook*, pages T12.3.5 - T12.3.11, "Troubleshooting Guide - Solids Handling."

3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*

    a. Aerobic Digestion, pages 325-334.
    b. Sludge Drying Beds, pages 350-355.
    c. Gravity Thickening, pages 285-286.
    d. Dissolved Air Flotation Thickening, pages 287-294.
    e. Vacuum Filtration, pages 335-343.
    f. Centrifugation, pages 325-334.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 12.3.1 - 12.3.32, Unit 12, Lesson 3.

2. Slides 179.2/12.3.1 - 179.2/12.3.53.

Instructor Materials Recommended for Development: If the instructor chooses to expand this lesson to include solids handling systems other than those covered in the lesson, appropriate instructional materials must be developed.

Additional Instructor References:

1. *Operation of Wastewater Treatment Plants, MOP 11*, Water Pollution Control Federation, Washington, D.C. (1976).

2. *Operations Manual: Sludge Handling and Conditioning*, EPA 430/9-78-002, Municipal Operations Branch, U.S. Environmental Protection Agency, Washington, D.C. (February, 1978).

3. Metcalf and Eddy, Inc., *Wastewater Engineering Treatment Disposal Reuse*, McGraw-Hill Book Company, New York (2nd Edition, 1979).

Classroom Set-Up: As specified for Unit 12, Lesson 1.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
I. Introduction to Solids Handling Processes (10 minutes)	Use Slide 179.2/12.3.1 Slide 179.2/12.3.1 is a blank
A. Different sludge handling processes have different functions - each has its own factors to consider in:	Use Slide 179.2/12.3.2 Slide 179.2/12.3.2 is a word slide which reads:
1. Whether or not to include in a plant	"Solids Handling Unit Processes
2. Actual design 3. Operation 4. Maintenance	Thickening (Blending) Stabilization (Reduction) Conditioning (Stabilization) Dewatering Heat Drying Reduction (Stabilization) Final Disposal"
	Refer to Unit of Instruction 12, Lesson 1, page 12.1.4 - 12.1.8 for detailed expansion of these points.
B. Functions of various unit processes of solids handling	
1. Each of the unit processes provides several functions in the handling of treatment plant sludge.	
2. Briefly review *Trainee Notebook*, pages 12.1.1 with class and review the function of each unit process.	Refer class to *Trainee Notebook*, page T12.1.1.
C. Types of solids handling processes	
1. Each unit process is typified by several specific processes.	
2. In most regions, many of these different processes may be found.	
3. Briefly review *Trainee Notebook*, pages T12.1.2 with class noting the types of of processes which will be covered in the remainder of this lesson.	Refer to *Trainee Notebook*, page T12.1.2, Unit Processes - Sludge Processing and Disposal

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
a. Gravity thickening	
b. Dissolved air flotation	Note: In some areas, some of these processes may not be used and should be excluded from the lesson.
c. Centrifugation	
d. Aerobic digestion	
e. Sludge drying beds	
f. Vacuum filtration	Note: Land disposal is presented As Unit of Instruction 13. This Unit may not be presented in every presention of the course materials.
4. Instructor should point out which processes are most widely used in the area where the course is being presented.	
II. Aerobic Digestion (20 minutes)	
A. Aerobic digesters are really activated sludge plants operated with very low F/M and long MCRT. Food is volatile solids. Respiration is endogenous.	
B. Areobic digesters are used, especially in in small plants, because they are simple to operate and not susceptible to upset.	Refer class to *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 316-324.
1. Aerobic Digestion Objectives	Use Slide 179.2/12.3.3 Slide 179.2/12.3.3 is a word slide which reads:
a. Stabilization	
b. Reduction	"Aerobic Digestion Objectives"
c. Conditioning	Stabilize Sludge Organics Reduce Sludge Mass and Volume Condition Sludge for Further Handling"

LESSON OUTLINE

2. Advantages of Aerobic Digestion Compared to Anaerobic Digestion
   a. Relatively simple operation.
   b. Small capital expenditures but larger O & M and energy costs.
   c. Few odors.
   d. Reduces pathogen count.
   e. Highly nitrified supernate low in BOD, SS and P.
3. Aerobic Digester System Components
   a. Sludge feed
      1) Usually intermittent fill and draw operation
      2) Some are continuous
   b. Aeration/mixing equipment
      1) Diffused air
      2) Mechanical surface aerators
   c. Supernatant draw-off
      1) Usually intermittent fill and draw operation
      2) If continuous, a solids separation device such as a clarifier is needed.
   d. Waste sludge draw-off
      1) Usually intermittent fill and draw operation

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/12.3.4

Slide 179.2/12.3.4 is a word slide which reads:

"Advantages of Aerobic Digestion

1. Relatively Simple to Operate
2. Requires Small Capital Expenditure
3. Does Not Generate Significant Odors and Reduces Number of Pathogenic Organisms
4. Produces a Highly Nitrified Effluent
5. Supernatant is Low in BOD, Solids and Total Phosphorous"

Use Slide 179.2/12.3.5

Slide 179.2/12.3.5 is a schematic diagram of a circular aerobic digester equiped with sparge turbine aeration/mixing equipment.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

2) If continuous feed will have solids separation device such as a final clarifier.

e. pH control

1) Aerobic digesters usually operate well into nitrification phase of biological reaction.

2) Nitrification causes pH to decrease because alkalinity is consumed in the reaction.

3) Some form of pH control is usually needed.

C. Normal Design and Operating Parameters

Refer Class to page T12.3.1 in the *Trainee Notebook.*

1. Application

   a. Primarily used on waste activated sludge.

   b. Most common application is at small treatment plants, less than 1 MGD or where technical competence is lacking.

2. Waste Activated Sludge

   a. Detention time 10-15 days.

   b. Solids loading 0.1 - 0.2 lbs of volatile matter per cubic foot per day.

   c. Anticipated volatile solids reduction, 60%.

3. Primary and Waste Activated Sludge

   a. Hydraulic detention time 15-25 days

   b. Solids loading 0.1 - 0.2 lbs of

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE

volatile matter per cubic foot per day.

D. Normal Operating Procedures

1. One advantage of aerobic digestion is that it is simple to operate and not susceptible to upset.

2. Sludge is introduced to the reactor on a continuous or hourly basis.

3. If continuously fed, a decanting facility is provided to thicken the digested sludge and return dense solids to the digester and supernatant liquor back to the secondary treatment system.

4. In fill and draw operations:

    a. Shut off air and mixing.

    b. Allow solids to settle.

    c. Decant supernatant.

    d. Withdraw concentrated digested sludge as appropriate.

    e. Restart air and mixing.

    f. Feed digester.

5. Dissolved oxygen should be maintained between one and two milligrams per liter.

6. Sludge can be concentrated to the extent where oxygen transfer is the limiting factor.

7. Sludge is drawn off for dewatering to avoid system overloading and oxygen transfer limitations.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
8. Aerobic digestion is temperature sensitive. At low temperatures digestion occurs very slowly. Few aerobic digesters are heated. Winter operation with its low rate of VS reduction can cause overload conditions during spring warm-up.	Note: There is some evidence that a properly insulated and covered aerobic digester will generate sufficient heat to maintain good cold weather operation. Digestion reactions are exothermic.
E. Typical Aerobic Digester Installations	
1. This view shows an 0.2 MGD plant with the clarifier in the center and aeration in a ring around it. The aerobic digester compartment is in the foreground. Sludge had been removed from this one regularly and its a good operation.	Use Slide 179.2/12.3.6 Slide 179.2/12.3.6 is a photograph of the aerobic digester compartment of a circular package treatment plant. The aerobic digester sludge is dark brown with a very slight foam cover.
2. This aerobic digester doesn't look so good. Scum disposal wasn't practiced. It was just collected and returned to the activated sludge aerator. The final clarifier was a mess because of greasy scum recycle to the aeration system. This much scum usually means inadequate disposal of both scum and solids, the only way out is via the discharge.	Use Slide 179.2/12.3.7 Slide 179.2/12.3.7 is a photograph of a rectangular aerobic digester showing a fairly heavy foam cover. The aerobic digester is mechanically mixed.
3. Here is the surface of one aerobic digester in operation. Have class critique this operation. a. Note that it's a well operated aerobic digester.	Use Slide 179.2/12.3.8 Slide 179.2/12.3.8 is a photograph showing the surface of an aerobic digester. The sludge is a deep brown color with a small amount of crisp, white foam.
b. This is the surface of the same aerobic digester after 2 hours of clarification for sludge disposal and supernating. The supernate in this case was exceptionally high in quality with less than 50 mg SS/liter. This can be done with good facilities, operation and maintenance. Scum and solids take-out for	Use Slide 179.2/12.3.9 Slide 179.2/12.3.9 is a photograph of an aerobic digester after aeration has been stopped and settling has been allowed to occur. The surface of the digester is covered with a thin film of ashy type material.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
disposal instead of recycle makes a tremendous improvement in performance.	
c. This is the air supply for the aerobic digester unit shown. The five blowers supply duplicate units. Two are adequate when weather is favorable for land disposal of solids; four have been used during spring warmup and extended wet weather.	Use Slide 179.2/12.3.10 Slide 179.2/12.3.10 is a photograph showing five drive motors and blowers used to aerate the digesters shown in Slides 179.2/12.3.8 and 9.
1) Low temperatures reduce digestion activity to almost nothing.	
2) Warmup results in organic overload symptoms.	
a) Excess foam.	
b) High oxygen demand	
c) Odors if insufficient aeration capacity to respond to the accumulated load.	
4. Surface aeration is used in this installation. The level may be changed to vary turbine submergence and air supply, but its still one unit with no standby capability. High MLSS, scum and the disposal record indicated insufficient sludge draw-off.	Use Slide 179.2/12.3.11 Slide 179.2/12.3.11 is a photograph of a aerobic digester with surface mechanical aeration and a relatively thick white foam.
5. When the sludge blanket is as close to to the top as this view shows it to be after three hours of settling, solids disposal may be needed. Overaeration is another possible cause. Mechanical shear or deflocculation may cause poor floc formation and poor settling. High digester D.O. (> 6 mg/l) would indicate possible over aeration. (Refer to Unit 11, Lesson 12 for more detailed discussion of over aeration.)	Use Slide 179.2/12.3.12 Slide 179.2/12.3.12 is a photograph showing an aerobic digester after the aeration has been stopped and the settling has been allowed. The sludge blanket is slightly below the liquid level but the liquid above the sludge is very clear.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
F. Troubleshooting Aerobic Digestion Problems	Guide: Use the next six slides to show sample troubleshooting problems. Refer class to *Trainee Notebook*, page T12.3.5 , "Troubleshooting Guide to Aerobic Digestion"
1. Low D.O. a. Have class critique photograph, Slide 179.2/12.3.13.	Use Slide 179.2/12.3.13 Slide 179.2/12.3.13 shows the surface of an aerobic digester covered with thick, almost dry, black, septic-looking surface foam.
b. Review problem and causes using Slide 179.2/12.3.14.	Use Slide 179.2/12.3.14 Slide 179.2/12.3.14 is a word slide which reads: "Troubleshooting Aerobic Digestion Problem: Low D.O. (below 1 mg/l) Causes: Insufficient Air, Heavy Load Corrections: Increase Air Supply, Unplug Aeration, Waste Solids"
2. Excessive detergent-like foam a. Have class critique photograph, Slide 179.2/12.3.15.	Use Slide 179.2/12.3.15 Slide 179.2/12.3.15 is a photograph showing surface of aerobic digester covered with thick, billowing white foam.
b. Review problem and causes using Slide 179.2/12.3.16.	Use Slide 179.2/12.3.16 Slide 179.2/12.3.16 is a word slide which reads: "Troubleshooting Aerobic Digestion Problem: Excessive Detergent Foam Causes: Low Solids in System Corrections: Increase Solids by Decanting and Recycling Solids If ineffective may be due to industrial ABS detergents - eliminate or depress"

LESSON OUTLINE

3. Thick, Gelatenous Foam

    a. Use Slide 179.2/12.3.17 for class critique.

    b. Use Slide 179.2/12.3.18 to present problem, causes and corrective actions.

III. Sludge Drying Beds (10 minutes)

A. Description of Facilities

1. Sludge drying beds are probably used more than any other method of sludge dewatering. They consist of a level area of sand, beneath which is a layer of gravel as an underdrain system. Beds are divided into sections by thick concrete walls or wood planks, which vary in size from 10 to 25 feet wide and from 50 to 150 feet long. Both open and covered beds are used, but open beds are most common for obvious economic reasons.

2. Before sludge is applied, the bed should be relatively smooth and clean. This is the most common error made in operating drying beds. The surface of

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/12.3.17
Slide 179.2/12.3.17 is a photograph of the surface of an aerobic digester covered with thick, dark, gelatenous foam.

Use Slide 179.2/12.3.18
Slide 179.2/12.3.18 is a word slide which reads:

"Troubleshooting Aerobic Digestion

Problem: Thick, Gelatenous Foam
Causes: High DO or Excessive Solids
Corrections: Lower Oxygen and/or Solids Input. In Some Digesters This is Normal and Not a Problem"

Use Slide 179.2/12.3.19
Slide 179.2/12.3.19 is a blank

Refer class to *Field Manual for Performance Evaluation and Troubleshoting at Municipal Wastewater Treatment Facilities*, pages 350-355.

Use Slide 179.2/12.3.20
Slide 179.2/12.3.20 is a schematic diagram of the cross-section of a sludge drying bed showing sludge inlet gate, splash slab, sand, gravel drainage and the sludge bed wall.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
large beds should be given a slight grade away from the point where the sludge is introduced so it will have a more uniform depth over the entire bed. In many instances where beds are made perfectly level, the sludge will be several inches thicker near the inlet.	
3. There is considerable difference in opinion as to the best depth which sludge should be put on the drying beds. The best method for determining the proper depth is by trial and error. When sludge is initially applied to a bed, drainage is quite rapid. After the media is blinded, then the majority of water loss is by evaporation. Allow at least 4 inches freeboard for expansion of anaerobic sludge.	
B. Design Considerations	Refer class to page T12.3.1 , *Trainee Notebook*
1. Anaerobically Digested Sludge	
a. Area required 1.0 to 3.0 ft^2 per capita.	
b. Average depth 6 to 18 inches.	
c. Average drying 1 to 6 weeks.	
2. Aerobically Digested Sludge	
a. Area required 1.0 to 2.0 ft^2 per capita.	
b. Average depth 8 - 18 inches.	
c. Average drying 1 - 4 weeks.	
3. General Configuration	
a. Should have underdrain system.	
b. Beds should be designed for easy cleaning.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
c. Size for average draw off	
C. Normal Operations of Drying Beds	
1. Program sludge application over at least a six-month period.	
a. Compute sludge production.	
b. Determine drying time at optimum depth.	
c. Develop routine program for draw off and bed cleaning.	
2. Sludge Application	Use Slide 179.2/12.3.21 Slide 179.2/12.3.21 is a word slide which reads:
a. Never apply sludge to a dirty bed.	
b. Never apply to excessive depths.	"Sludge Drying Beds - Normal Operations Compute and Program Draw Offs Draw Sludge Off Only to a Clean Bed Not to Excessive Depth (8" normal) Bed Cleaning Remove When Sludge is Well Cracked (30-40% solids) Rake Level and Apply New Sand"
1) Usually eight inches is a standard depth.	
2) Actual depth should be determined experimentally for optimum drying time.	
3) Leave about 4 inches free board for sludge expansion.	
3. Sludge Bed Cleaning	
a. Removal should be accomplished when sludge is well cracked (30-40% solids).	
b. After removal bed should be raked level and new sand applied if necessary.	
D. Process Evaluation for Drying Beds	Use Slide 179.2/12.3.22 Slide 179.2/12.3.22 is a word slide which reads:

LESSON OUTLINE

1. Use Slide 179.2/12.3.22 to review data needed to evaluate drying bed performance.

2. Refer class to *Trainee Notebook*, page T12.3.6.

E. Common Problems to Troubleshoot with Sludge Drying Beds

1. The most common and serious problem is excessive dewatering time.

2. Use Slide 179.2/12.3.23 to review causes of problems.

3. Have class discuss possible solutions to problems. Refer to *Trainee Notebook*, page T12.3.6.

4. Polymers or coagulant aids, such as ferric salts or alum, may be added to accelerate dewatering rates.

IV. Gravity Thickening (10 minutes)

A. A gravity thickener resembles a clarifier, where sludge settles and thickens. Briefly discuss diagram with students. Point out picket mechanism which aids in release of bound water.

B. Troubleshooting Gravity Thickeners

1. Troubleshooters should be familiar with normal operating procedures and conditions.

KEY POINTS & INSTRUCTOR GUIDE

"Drying Beds - Process Evaluation

Compare Sludge Production to
  Area Available
Use Records and Log to Determine
  Actual Sludge Application
  Actual Drying Time
  Sand Replacement"

Use Slide 179.2/12.3.23

Slide 179.2/12.3.23 is a word slide which reads:

"Causes of Excessive Dewatering Time on Sludge Drying Beds

Overload of Sludge
Application on Uncleaned Bed
Dirty Sand on Bed
Plugged Underdrain System
Weather Conditions
Septic Sludge
Wrong Chemical Dose"

Refer trainees to *Trainee Notebook*, page T12.3. , for corrections to these problems. Briefly discuss.

Use Slide 179.2/12.3.24

Slide 179.2/12.3.24 is a blank.

Use Slide 179.2/12.3.25

Slide 179.2/12.3.25 is a schematic diagram of a cross section of a gravity thickener.

Refer class to page 282, *Field Guide for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*.

Use Slide 179.2/12.3.26

Slide 179.2/12.3.26 is a word slide which reads:

LESSON OUTLINE

a. Review points on Slide 179.2/12.3.26

b. Refer class to *Trainee Notebook*, page T12.3.1 for summary of normal operating conditions.

c. Important observations

   1) Observe surface for gas bubbles

   2) Odors

2. To evaluate a gravity thickening process, troubleshooters should test and determine the following parameters.

   a. Primary Sludge

      1) Hydraulic loading, less than 900 gal/ft^2/day

      2) Solids loading, 15-30 lbs/ft^2/day

      3) Underflow concentration, 8-10%

      4) Supernatant concentration, approximately equal to raw sewage

   b. Primary and Trickling Filter Sludge

      1) Hydraulic loading, less than 500 gal/ft^2/day

      2) Solids loading 10-20 lbs/ft^2/day

      3) Underflow concentration, 7-9%

      4) Supernatant concentration approximately equal to raw sewage

   c. Activated Sludge

KEY POINTS & INSTRUCTOR GUIDE

"Gravity Thickeners - Normal Operations"

Sludge Pumped Continuously Into Thickener
Concentrated Sludge Should Be Removed Continuously
Small Plants - Remove Hourly
Check Concentrations Daily
Check Supernatant Solids Weekly"

Use Slide 179.2/12.3.27

Slide 179.2/12.3.27 is a word slide which reads:

"Troubleshooting Gravity Thickeners Process Tests

Hydraulic Loading
Solids Loading
Compute Mass Balance in System
Immediate Oxygen Demand (IOD)
Average Underflow and Overflow Solids Concentrations"

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

1) Hydraulic loading, less than 300 gal/ft^2/day

2) Solids loading, 4-8 lb solids/ft^2/day

3) Underflow concentration, 2-3%

4) Supernatnat concentration, 50-150 mg/l suspended solids

d. Primary and Activated Sludge

1) Hydraulic loading, less than 500 gal/ft^2/day

2) Solids loading, 6-10 lbs/ft^2/day

3) Underflow concentration, 5-8%

4) Supernatant concentration approximately equal to raw sewage

3. Troubleshooting gravity thickeners

a. Refer class to *Trainee Notebook*, page T12.3.7 , for troubleshooting guides.

b. Use slides to discuss thickener troubleshooting.

1) Process evaluation measures

a) Determine the hydraulic loading.

b) Determine the solids loading.

c) Compute a mass balance around the system

d) Determine the IOD of the system (indicates septicity)

LESSON OUTLINE

2) Problem Identification and correction

   a) Low thickened sludge concentration

      1. Possible cause - over pumping of thickened sludge or pumping at improper rate

         a. Characterized by:

            (1) Hydraulic and solids loading, normal
            (2) Mass balance, normal
            (3) Supernatant within specs, low IOD, solids normal
            (4) No odor
            (5) No gas bubbles

         b. Corrective measure:

            (1) Modify sludge pumping rate from thickener by computing required rate

   b) Possible cause - thickener becomes septic

      1. Characterized by:

         a. Odor from thickener

         b. High IOD in supernatant

         c. High solids in supernatant

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/12.3.28
Slide 179.2/12.3.29 is a word slide which reads:

"Troubleshooting Operational Problems in Gravity Thickeners

Most Common Problem: Low sludge concentration
Likely Causes: Septic thickener, pumping sludge at wrong rate
Corrections: Increase pumping, add chlorine; drain thickener"

- d. Septic liquified thickened sludge
- e. High volatile acid concentration in thickened sludge

2. Corrective measures
    - a. Increase sludge pumping
    - b. Add chlorine
    - c. Drain thickener contents to digester, wash down and start over again
    - d. The above corrective measures should be attempted in sequence where c. is the most drastic measure
    - e. Check pumps, valves
    - f. Reduce possible overloading of tank
    - g. Add air 1 to 2 feet below surface or in wet well
    - h. Recycle up to hydraulic load capacity
    - i. Blend secondary effluent with thickener feed as D.O. source

Use Slide 179.2/12.3.29
Slide 179.2/12.3.29 is a blank.

LESSON OUTLINE

V. Dissolved Air Flotation Thickening (DAF) (10 minutes)

   A. Use Slide 179.2/12.3.30 to describe components of a DAF thickener.

   B. Use Slide 179.2/12.3.31 to describe components of DAF system. (Refer class to pages 287-294, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities.*)

   C. Normal Operations

      1. Primary sludge thickening

         a. Hydraulic loading, 1,000-2,500 gal/ft^2/day

         b. Solids loading, 50 lbs/ft^2/day

         c. Float solids concentration, 6-8%

         d. Subnatant solids concentration equal to raw sewage

      2. Activated Sludge Thickening

         a. Hydraulic loading, approximately 2,000 gal/ft^2/day

         b. Solids loading, 10-15 lbs/ft^2/day

         c. Float solids concentration, 3-4% (3.5-5% with polymers)

         d. Subnatant solids concentration, 50-200 mg/l suspended solids

      3. Primary and Waste Activated Sludge Thickening

         a. Hydraulic loading, approximately 2,000 gal/ft^2/day

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/12.3.30
Slide 179.2/12.3.30 is a schematic diagram showing the cross section of a dissolved air flotation thickener

Use Slide 179.2/12.3.31
Slide 179.2/12.3.31 is a schematic diagram showing the air dissolution retention tank, recirculation pump, and flotation unit as part of the overall DAF system.

Refer class to *Trainee Notebook*, page T12.3.2

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. Solids loading, 15-30 lbs/ft^2/day	
c. Float solids concentration, 5-7%	
d. Subnatant solids concentration, approximately equal to raw sewage	
4. Normal Operating Procedures	Use Slide 179.2/12.3.32 Slide 179.2/12.3.32 is a word slide which reads:
a. Systems are usually fed continuously.	"Flotation Units - Normal Operation
b. Float is skimmed continuously while being fed.	Feed System Continuously Skim and Remove Floating Sludge Continuously
c. Bottom sludge accumulations removed every 4 to 8 hours.	Remove Bottom Sludge Every 4-8 Hours"
d. Air to solids ratio checked daily by visual observation of float.	
1) If float is excessively frothy, air injection rate is reduced.	
2) If excessive solids are accumulating on the bottom, air injection rate is increased. If too much agitation, decrease.	
D. Troubleshooting DAF Thickening	Refer class to *Trainee Notebook*, page T12.3.8
1. Use Slide 179.2/12.3.33 to review tests and observations required to evaluate air flotation units.	Use Slide 179.2/12.3.33 Slide 179.2/12.3.33 is a word slide which reads:
a. Determine hydraulic loading	"Tests and Observations for Flotation Units
b. Determine solids loading	
c. Determine average float solids concentration	Observe Float to Determine Air to Solids Ratio Hydraulic Loading Solids Loading Solids Concentration Subnatant Solids Concentration
d. Determine average subnatant solids concentration	Compute Mass Balance for Unit"
e. Compute mass balance around the system	

LESSON OUTLINE

2. Common Problems
    a. Low float solids concentration
        1) Possible cause - excessive skimming
            a) Characterized by:
                1. Hydraulic loading - normal
                2. Solids loading - normal
                3. Float OK - not frothy due to excessive air
                4. Air to solids ratio - normal
            b) Corrective measures - reduce skimmer speed to achieve maximum thickness without having excessive solids carryover.
        2) Possible cause - excessive air/solids ratio
            a) Characterized by:
                1. Hydraulic loading, OK
                2. Solids loading, OK
                3. Float extremely frothy
            b) Corrective measures
                1. Reduce air to pressurization system, or
                2. Increase solids load to thickener.
                3. Obtain recycle rate of 1:1 to 3:1.

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/12.3.34

Slide 179.2/12.3.34 is a word slide which reads:

"Troubleshooting Air Flotation

Problem: Low float solids concentration
Causes: Excessive skimming, excessive air/solids ratio
Corrections: Reduce air, increase solids load, reduce skimmer speed"

b. Poor Capture

1) Possible causes
   - a) Hydraulically overloaded
   - b) High solids loading
   - c) Low A/S ratio
   - d) Low removal or skimming rate
   - e) Poor rise rate

2) Hydraulic or solids overload
   - a) Check first, if satisfactory then check

3) A/S solids loading
   - a) Check, characterized by poor float formation solids settling to the bottom. If normal, then check

4) Skimming rate
   - a) Characterized by good thick float, but excessively deep to the point where it is coming up under the baffle if rate is too low. If normal, then check

5) Poor rise rate
   - a) Characterized by high sludge volume index, poor float density and dispersed floc.

Use Slide 179.2/12.3.35
Slide 179.2/12.3.35 is a word slide which reads:

"Troubleshooting Air Flotation"

> Problem: Poor capture of solids
> Causes: Hydraulic or solids overload, Low air/solids ratio, low skimming rate
> Corrections: Increase air, increase skimming rate"

Use Slide 179.2/12.3.36
Slide 179.2/12.3.36 is a blank

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
VI. Vacuum Filtration (10 minutes)	Refer class to page 335-345, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*
A. Vacuum filtration is one of the mechanical means of sludge dewatering. 1. Use Slide 179.2/12.3.37 to describe components.	Use Slide 179.2/12.3.37 Slide 179.2/12.3.37 is a schematic diagram of a cut-away view of a rotary drum vacuum filter.
B. Normal Operations of a Vacuum Filter 1. Process Application, Parameters and Anticipated Performance a. Primary Sludge Dewatering 1) Loading + Yield, 4-10 lbs/ft^2/hr 2) Feed concentration, 5-10% 3) Cake solids concentration, 20-35% b. Primary and Waste Activated Sludge 1) Loading + Yield, 3-5 lbs/ft^2/hr 2) Feed concentration, 3-6% 3) Cake solids concentration, 15-25% c. Anaerobically Digested Sludge 1) Loading + Yield, 3-8 lbs/ft^2/hr 2) Feed concentration, 3-5% 3) Cake solids concentration, 15-25% d. Most common chemicals used in pre-conditioning	Use Slide 179.2/12.3.38 Slide 179.2/12.3.38 is a word slide which reads: " Vacuum Filters - Normal Operations" Sludge is Fed Continuously Sludge is Chemically Conditioned Continuously Operate Filter Drum at Optimum Speed to Get Thick Cake to Drop Off to Conveyor Most Systems Operate Well with Proper Chemicals and Filter Media"

LESSON OUTLINE

1) Lime (CaO or $CaOH$) (5-15%)

2) Ferric Chloride ($FeCl$) (2-10%)

3) Polymer (0.3-2.5%) usually cationic

2. Use Slide 179.2/12.3.38 to review normal operational procedures.

C. Process Evaluation Measures

1. Determine solids loading

2. Determine cake concentration

3. Determine filtrate concentration

   a. Should be less than 1.0%

4. Determine chemical dosages

5. Check dewaterability at dosage being used

6. Check filter cloth condition

   a. Should be clean and not blinded

D. Troubleshooting Operational Problems in Vacuum Filters

1. Thin poorly dewatered cake

   a. Possible causes

      1) Blind cloth

      2) Improper chemical dosage

      3) Low vacuum

      4) Improper cloth

      5) Speed too fast

      6) Submergence

KEY POINTS &
INSTRUCTOR GUIDE

Use Slide 179.2/12.3.39

Slide 179.2/12.3.39 is a word slide which reads:

"Process Evaluation for Vacuum Filters"

Tests and Observations to Make:

Solids Loading
Cake Concentration
Filtrate Concentration
Chemical Dosages
Dewaterability at Applied Dosage
Filter Cloth Condition"

Use Slide 179.2/12.3.40

Slide 179.2/12.3.40 is a word slide which reads:

"Troubleshooting Vacuum Filters

Problem: Thin cake, Poorly dewatered
Causes: Blind cloth, chemical dosage, vaccum, speed
Corrections: Clean cloth, determine proper chemical dose, overhaul vacuum pump and lines"

LESSON OUTLINE

- b. Corrective measures
  - 1) Blind cloth
    - a) If dirty, steam clean and scrub with hot detergent
  - 2) Improper chemicals
    - a) Determine proper dosage for good dewatering, then apply these dosages to the actual filter. Make field adjustments to achieve optimum results.
  - 3) Low vacuum in system
    - a) Check all lines and relief valves for leaks. Check drum operation and seals.
    - b) Repair where necessary or overhaul the vacuum pump.
  - 4) Improper cloth (media)
    - a) Check by running leaf test with best dewatered sludge. Run with different types of media until best one is observed. Change on actual filter if necessary.

2. Thick Poorly Dewatered Cake
   - a. Possible causes
     - 1) High drum speed
     - 2) Low vacuum
     - 3) Too high a feed rate

KEY POINTS & INSTRUCTOR GUIDE

Use Slide 179.2/12.3.41

Slide 179.2/12.3.41 is a word slide which reads:

"Troubleshooting Vacuum Filters

Problem: Thick cake, poorly dewatered

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
b. Corrective measures 1) High drum speed a) Slow drum speed and observe difference in cake dryness. Sometimes filters have the ability to remove solids at a higher design rate, but this usually results in high moisture content. 2) Low vacuum pressure a) This is usually associated with low yield, although the filter cake is thick. Normally the drum speed is slowed down to compensate for the low vacuum. b) If vacuum is low, check piping, relief valves (if any) and seats in the filter system. Repair where necessary. 3) Excessive feed rate a) Check solids yield on filter cloth. b) If excessive, reduce feed rate and chemical dosage rate accordingly.	Causes: High drum speed, high feed rate, low vacuum Corrections: Lower drum speed, check and repair vacuum system, reduce feed rate"
VII. Centrifugation (10 minutes)	Use Slide 179.2/12.3.42 Slide 179.2/12.3.42 is a blank
A. Uses rotation and centrifugal force to separate solids from liquid, thicken sludge. There are several types:	
1. Basket centrifuge 2. Rotating bowl centrifuge (most commonly used)	Use Slide 179.2/12.3.43 Slide 179.2/12.3.43 is a schematic diagram of solid bowl centrifuge

LESSON OUTLINE

3. It is difficult to specify procedures to troubleshoot a centrifuge without knowing the exact design intent.

4. Use Slide 179.2/12.3.43 to review components of solid bowl centrifuge.

B. Normal Operation

1. If polymers are to be used, a jar test should be made to determine best apparent dosage and then field tested.

2. Some judgment should be made as to cost of chemicals vs. capture and solids density.

3. Centrifuge is started and sludge is then fed to the unit. Feed rate is increased to achieve desired results.

   a. The lower the feed rate, the better the capture but % solids decreases.

   b. A lower pool depth produces a drier cake, also less capture.

   c. A high pool depth produces better capture and clarity of centrate.

   d. A compromise between b. and c. normally produces the best all around results.

4. The amount of solids to be dewatered should be determined and then programmed into an operating schedule. Too often the operating schedule dictates the dewatering time.

C. Process Evaluation Measures

KEY POINTS & INSTRUCTOR GUIDE

Refer class to pages 325-334, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities.*

Use Slide 179.2/12.3.44

Slide 179.2/12.3.44 is a word slide which reads:

"Centrifuge Variables

Control	> Cake Solids	> Solids Recovery
1. Feed Rate	Increase	Decrease
2. Feed Solids	Decrease	Increase
3. Temperature	Increase	Increase
4. Flocculents	No	Yes
5. Bowl Speed	Increase	Increase
6. Pool Volume	Decrease	Increase
7. Conveyor Speed	Decrease	Decrease"

Use Slide 179.2/12.3.45

Slide 179.2/12.3.45 is a word slide which reads:

LESSON OUTLINE

Note: It is not possible to give exact procedures as to process evaluation without knowing the exact design intent. Normally in anaerobic sludge centrate quality is more significant than solid cake density.

1. Determine solids volume to be dewatered.

2. Determine capacity of unit based on past experience if available.

3. Evaluate capture vs. centrate quality.

D. Process Application, Parameters and Anticipated Performance

1. Raw Primary Sludge

    a. Capture, 80-90%

    b. Solids, 25-30%

    c. Chemicals, not normally utilized

2. Anaerobically Digested Sludge

    a. Capture, 70-95%

    b. Solids, 15-25%

    c. Chemicals, polymers 0.05-3%

3. Aerobically Digested Sludge

    a. Capture, 70-95%

    b. Solids, 15-20%

    c. Chemicals, polymers 0.05-2%

4. General

    a. Most centrifuges are of the solid bowl type

KEY POINTS & INSTRUCTOR GUIDE

"Tests and Observations for Centrifuges

Solids Volume to be Dewatered
Capture Rate Compared to Centrate Quality
Polymer Type and Dosage"

Refer to *Trainee Notebook*, page T12.3.3

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
1) Cylindrical solid bowl gives good capture. 2) Conical solid bowl renders a good dense sludge. 3) A combination of the above renders a compromise between the two units.	
E. Troubleshooting Problems in Centrifuge Operations 1. Poor capture, cake density good a. Check pool depth if applicable and raise b. Lower feed rate if possible c. Add more polymer or evaluate other polymers for better capture	Use Slide 179.2/12.3.46 Slide 179.2/12.3.46 is a word slide which reads: "Troubleshooting Centrifuges Problem: Poor solids capture, cake density good Causes: Pool depth, feed rate, polymer type and dosage Corrections: Raise pool depth, lower feed rate if possible, change polymers"
2. Cake density low, capture satisfactory a. Check pool depth, if high, lower until better density is obtained (if applicable). b. Vary dosage of polymer c. Consider increasing bowl speed	Use Slide 179.2/12.3.47 Slide 179.2/12.3.47 is a word slide which reads: "Troubleshooting Centrifuges Problem: Good capture, low density cake Causes: Pool depth, polymer, bowl speed Corrections: Lower pool depth, vary polymer, increase bowl speed"
3. Low cake density, poor capture a. Check feed rate. It may be too high. b. Check polymer dosage. Should clear up centrate.	Use Slide 179.2/12.3.48 Slide 179.2/12.3.48 is a word slide which reads: "Troubleshooting Centrifuges

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
c. Check pool depth. Could be excessively high or low.	Problem: Poor capture, low cake density, i.e., combination of first 2 problems Corrections: Lower feed rate, change polymer dosage, vary pool depth"
4. Capture and cake density normal, but machine will not handle daily solids production.	Use Slide 179.2/12.3.49 Slide 179.2/12.3.49 is a word slide which reads:
a. Consider increasing flow to centrifuge and sacrifice centrate quality. b. Check with manufacturer with regard to increasing bowl speed. c. Increase aeration time. d. Add chemicals e. Change speed ratio f. Check to see if characteristics of feed have changed.	"Troubleshooting Centrifuges Problem: Good capture, but insufficient capacity to handle daily load Corrections: Increase flow, increase bowl speed, increase aeration time, add polymers"
5. In summarizing this section, point out that in troubleshooting equipment like centrifuges, the troubleshooter may do well to consult others as well, such as: a. Operators b. Equipment manufacturers c. Service representatives d. Senior personnel in your Agency e. EPA specialists	Use Slide 179.2/12.3.50 Slide 179.2/12.3.50 is a blank
VIII. Summary and Questions (10 minutes)	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
A. Summarize lesson	
1. Use Slide 179.2/12.3.51 to summarize solids handling methods and functions.	Use Slide 179.2/12.3.51 Slide 179.2/12.3.51 is a word slide which reads: "Methods of Solids Handling Thickening - Gravity Thickening - Flotation - Centrifugation Stabilization - Aerobic Digestion Dewatering - Sludge Drying Beds - Vacuum Filtration"
2. Use Slide 179.2/12.3.52 to summarize the common solids handling problems. a. Note that solids disposal is covered in a separate unit of instruction on Land Application, Unit of Instruction 13. b. One problem not listed is inadequate solids handling capacity. Frequently requires a long term corrective action in design and construction.	Use Slide 179.2/12.3.52 Slide 179.2/12.3.52 is a word slide which reads: "Principal Problems in Sludge Handling Low Sludge Concentration Poor Capture of Solids Septicity Poor Dewatering Final Disposal and the Problems it Creates"
B. Questions and Discussions Use any remaining time for general discussion about solids handling problems.	Use Slide 179.2/12.3.53 Slide 179.2/12.3.53 is a blank

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 12: Solids Handling

Lesson 3: Other Methods of Solids Handling

Trainee Notebook Contents

Typical Performance Characteristics of Solids Handling Systems T12.3.1

Troubleshooting Guide T12.3.5

Typical Performance Characteristics of Solids Handling Systems

A. Aerobic Digestion - Process Application, Parameters and Anticipated Performance

1. Application
    - a. Primarily used on waste activated sludge
    - b. Most common application is on small treatment plants, less than 1 MGD or where technical competence is lacking
2. Waste Activated Sludge
    - a. Detention time 10-15 days
    - b. Solids loading 0.1-0.2 lbs of volatile matter per cubic foot per day
    - c. Anticipated volatile solids reduction, 60%
3. Primary and Waste Activated Sludge
    - a. Hydraulic detention time 15-25 days
    - b. Solids loading 0.1-0.2 lbs of volatile matter per cubic foot per day

B. Sludge Drying Beds - Process Application, Parameters and Anticipated Performance

1. Anaerobically Digested Sludge
    - a. Area required 1.0 to 3.0 ft^2 per capita
    - b. Average depth 6 to 18 inches
    - c. Average drying 1 to 6 weeks
2. Aerobically Digested Sludge
    - a. Area required 1.0 to 2.0 ft^2 per capita
    - b. Average depth 8-18 inches
    - c. Average drying 1-4 weeks
3. General Configuration
    - a. Should have under drain system
    - b. Beds should be designed for easy cleaning
    - c. Size for average draw off

C. Gravity Thickeners - Process Application, Parameters and Anticipated Performance

1. Primary Sludge
    - a. Hydraulic loading less than 900 gal/ft^2/day
    - b. Solids loading, 15-30 lbs/ft^2/day
    - c. Underflow concentration, 8-10%
    - d. Supernatant concentration, approximately equal to raw sewage

2. Primary and Trickling Filter Sludge

    a. Hydraulic loading less than 500 gal/ft^2/day
    b. Solids loading, 10-20 lbs/ft^2/day
    c. Underflow concentration, 7-9%
    d. Supernatant concentration approximately equal to raw sewage

3. Activated Sludge

    a. Hydraulic loading less than 300 gal/ft^2/day
    b. Solids loading, 4-8 lb solids/ft^2/day
    c. Underflow concentration, 2-3%
    d. Supernatant concentration, 50-150 mg/l suspended solids

4. Primary and Activated Sludge

    a. Hydraulic loading less than 500 gal/ft^2/day
    b. Solids loading, 6-10 lbs/ft^2/day
    c. Underflow concentration, 5-8%
    d. Supernatnat concentration approximately equal to raw sewage

Observe surface for gas bubbles

Observe system for odor

Determine the average underflow solids concentration

Determine the average overflow solids concentration

D. Dissolved Air Flotation - Process Application, Parameters and Anticipated Performance

1. Primary Sludge Thickening

    a. Hydraulic loading, 1,000-2,500 gal/ft^2/day
    b. Solids loading, 50 lbs/ft^2/day
    c. Float solids concentration, 6-8%
    d. Subnatant solids concentration equal to raw sewage

2. Activated Sludge Thickening

    a. Hydraulic loading, approximately 2,000 gal/ft^2/day
    b. Solids loading, 10-15 lbs/ft^2/day
    c. Float solids concentration, 3-4% (3.5-5% with polymers)
    d. Subnatant solids concentration - 50-200 mg/l suspended solids

3. Primary and Waste Activated Sludge Thickening

    a. Hydraulic loading, approximately 2,000 gal/ft^2/day
    b. Solids loading, 15-30 lbs/ft^2/day
    c. Float solids concentration, 5-7%
    d. Subnatant solids concentration approximately equal to raw sewage

4. Normal Operating Procedures
    a. Systems are usually fed continuously
    b. Float is skimmed continuously while being fed
    c. Bottom sludge accumulations removed every 4 to 8 hours
    d. Air to solids ratio checked daily by visual observation of float
        1) If float is excessively frothy, air injection rate is reduced
        2) If excessive solids are accumulating on the bottom, air injection rate is increased. If too much agitation, decrease.

E. Vacuum Filtration - Process Application, Parameters and Anticipated Performance

1. Primary Sludge Dewatering
    a. Loading and Yield, 4-10 lbs/ft^2/hr
    b. Feed concentration, 5-10%
    c. Cake solids concentration, 20-30%
2. Primary and Waste Activated Sludge
    a. Loading and Yield, 3-5 lbs/ft^2/hr
    b. Feed concentration, 3-6%
    c. Cake solids concentration, 15-25%
3. Anaerobically Digested Sludge
    a. Loading and Yield, 3-8 lbs/ft^2/hr
    b. Feed concentration, 3-5%
    c. Cake solids concentration, 15-25%
4. Most Common Chemicals Used in Pre-Conditioning
    a. Lime (CaO or CaOH)
    b. Ferric Chloride (FeCl) (2-10%)
    c. Polymer (0.3-2.5%) usually cationic

F. Sludge Centrifugation - Process Application, Parameters and Anticipated Performance

1. Raw Primary Sludge
    a. Capture, 80-90%
    b. Solids, 25-30%
    c. Chemicals, not normally utilized
2. Anaerobically Digested Sludge
    a. Capture, 70-95%
    b. Solids, 15-25%
    c. Chemicals, polymers 0.05-3%

3. Aerobically Digested Sludge
    a. Capture, 70-95%
    b. Solids, 15-20%
    c. Chemicals, polymers 0.05-2%
4. General
    a. Most centrifuges are of the solid bowl type
        1) Cylindrical solid bowl gives good capture
        2) Conical solid bowl renders a good dense sludge
        3) A combination of the above renders a compromise between the two units

Troubleshooting Guide - Solids Handling

I. Aerobic Digestion

A. Process Evaluation Measures

1. Determine dissolved oxygen
2. Determine solid concentration
3. Determine rate of air supply

B. Problem Identification and Correction

1. Low dissolved oxygen

a. Possible causes

1) Insufficient air supply
2) Sludge overload

b. Corrections

1) Increase air supply if diffused air
2) Increase submergence if mechanical
3) If maximum air is being introduced, lower solids content by drawing solids off to drying beds or other methods of disposal
4) System may have received an unusual heavy loading. Check O_2 uptake. Observe for several days. Oxygen uptake should subside and D.O. should increase. If not, waste solids.
5) Check on system - diffuser plugged
6) Blocking of mechanical aeration

2. Excessive Detergent-Like Foam

a. Characterized by white to light brown light billowy foam. May look like soapsuds.
b. Probably causes

1) Low solids in the system
2) ABS (non-biodegradable) detergents

c. Corrections

1) Increase solids to approximately 1.5% or more by decanting and recycling solids back to system
2) If solids concentration is sufficient, foam may be caused by non-biodegradable detergents (i.e., ABS) discharged by industry, usually textile. Correct by eliminating discharge, could use foam sprays in conjunction with a silicon based foam depressant for temporary relief.

3. Excessive Gelatenous Foam

a. Characterized by a thick gelatenous foam that may cover entire reactor

b. Caused by excessive cell lysing usually associated with extremely high dissolved oxygen concentration and high solids retention time

c. Correction: lower oxygen input and/or solids in the system

d. Note: Protoplasmic Foam may not necessarily be a problem if contained within the reactor and desired results are obtained. Many aerobic digesters operate this way.

II. Sludge Drying Beds

A. Process Evaluation Measures

1. Check sludge production against area available
2. Check records to determine actual application
3. Check records for actual drying time
4. Check records for sand replacement

B. Problem Identification and Correction - the most common problem is excessive dewatering time

1. Possible Causes

a. Excessive application of sludge on bed
b. Application of sludge on uncleaned bed
c. Dirty sand on bed surface
d. Plugged under drain system
e. Weather conditions
f. Septic sludge
g. Wrong chemical dose

2. Corrective Measures

a. Excessive application of sludge on bed

1) When bed does dry, clean and prepare properly. Then apply a smaller amount (depth) on bed and evaluate. After sand media blinds the rest of the water is removed by evaporation. A good rule of thumb is to apply a load of sludge and measure the drawn down for the first three days. Twice the draw down should be the next application.

b. Application of sludge on an uncleaned bed

1) Little or no percolation will be observed. No corrective measures other than recognizing the problem and not doing it again.

c. Dirty sand on bed surface

1) No corrective measures advised after sludge has been drawn. After sludge has dried, remove sludge and dirty sand. Replace with 1-2 mm clean sand.

d) Plugged under drain system

1) With beds empty tie into underdrain piping with clean

water and backflush into beds. Note: Always start water into beds slowly. Repeat this process until beds drain rapidly with the clear water. Broken pipes are a real possibility.

2) A plugged underdrain system means that somehow sludge was allowed to enter the drain system. The media above the drain should be evaluated and replaced.

e. Insufficient capacity to handle sludge production

1) Evaluate use of polymer. Normally high molecular weight cationic polymer works best. Normal dosage 5-30 lbs per ton of dry solids depending on molecular weight and charge.

2) Ferric sulfate is often used as a coagulant aid without damaging the usefulness of the sludge as a fertilizer. In many areas it can be purchased as spent pickle liquor. Ferric chloride may be used.

III. Gravity Thickeners

A. Process Evaluation Measures

1. Determine the hydraulic loading
2. Determine the solids loading
3. Compute a mass balance around the system
4. Determine the IOD of the system (Immediate Oxygen Demand)

B. Problem Identification and Correction

1. Low thickened sludge concentration

   a. Possible cause - over pumping of thickened sludge or pumping at improper rate

      1) Characterized by:

         a) Hydraulic and solids loading, normal
         b) Mass balance, normal
         c) Supernatant within specs, low IOD, normal
         d) No odor
         e) No gas bubbles

      2) Corrective measure

         a) Modify sludge pumping rate from thickener by computing required rate

   b. Possible cause - thickener becomes septic

      1) Characterized by:

         a) Odor from thickener
         b) High IOD in supernatant
         c) High solids in supernatant
         d) Septic liquified thickened sludge
         e) High volatile acid concentration in thickened sludge

2) Corrective measures:

   a) Increase sludge pumping
   b) Add chlorine
   c) Drain thickener contents to digester wash down and start over again
   d) The above corrective measures should be attempted in sequence where (c) is the most drastic
   e) Check pumps, valves
   f) Reduce possible overloading of tank
   g) Add air 1 to 2 feet below surface or in wet well
   h) Recycle up to hydraulic load capacity
   i) Blend secondary effluent with thickener feed as D.O. source

IV. Dissolved Air Flotation Thickening

A. Process Evaluation Measures

1. Determine hydraulic loading
2. Determine solids loading
3. Determine average float solids concentration
4. Determine average subnatant solids concentration
5. Compute mass balance around the system

B. Problem Identification and Correction

1. Low float solids concentration

a. Possible cause - excessive skimming

1) Characterized by:

   a) Hydraulic loading, normal
   b) Solids loading, normal
   c) Float OK, not frothy due to excessive air
   d) Air to solids ratio, normal

2) Corrective measure

   a) Reduce skimmer speed to maximum thickness without having excessive solids carry over

b. Possible cause - excessive air/solids ratio

1) Characterized by:

   a) Hydraulic loading, OK
   b) Solids loading, OK
   c) Float extremely frothy

2) Corrective measures

   a) Reduce air pressurization system, or
   b) Increase solids load to thickener
   c) Obtain recycle rate of 1:1 to 3:1

2. Poor capture

   a. Possible causes

      1) Hydraulically overloaded
      2) High solids loading
      3) Low A/S ratio
      4) Low removal or skimming rate
      5) Poor rise rate

   b. Hydraulic or solids overload

      1) Check first, if satisfactory then check

   c. Air/solids loading

      1) Check, characterized by poor float formation solids settling to the bottom. If normal, then check

   d. Skimming rate

      1) Characterized by good thick float but not excessively deep to the point where it is coming up under the baffle if rate is too low. If normal, then check

   e. Poor rise rate

      1) Characterized by high sludge volume index, poor float density and dispersed floc

V. Vacuum Filtration

   A. Process Evaluation Measures

      1. Determine solids loading
      2. Determine cake concentration
      3. Determine filtrate concentrate
         a. Should be less than 1.0%
      4. Determine chemical dosages
      5. Check dewaterability at dosage being used
      6. Check filter cloth condition
         a. Should be clean and not blinded

   B. Problem Identification and Correction

      1. Thin poorly dewatered cake

         a. Possible causes

            1) Blind cloth
            2) Improper chemical dosage
            3) Low vacuum
            4) Improper cloth
            5) Speed too fast
            6) Submergence

b. Corrective measures

1) Blind cloth

a) If dirty, steam clean and scrub with hot detergent

2) Improper chemicals

a) Determine proper dosage for good dewatering, then apply these dosages to the actual filter. Make field adjustments to achieve optimum results.

3) Low vacuum in system

a) Check all lines and relief valves for leaks, check drum operation and seals
b) Repair where necessary or overhaul the vacuum pump

4) Improper cloth (media)

a) Check by running leaf test kit with best dewatered sludge. Run with different types of media until best one is observed. Change on actual filter if necessary.

2. Thick poorly dewatered cake

a. Possible causes

1) High drum speed
2) Low vacuum
3) Too high a feed rate

b. Corrective measures

1) High drum speed

a) Slow drum speed and observe difference in cake dryness. Sometimes filters have the ability to remove solids at a higher than design rate, but this usually results in high moisture content.

2) Low vacuum pressure

a) This is usually associated with low yield, although the filter cake is thick. Normally the drum speed slowed down to compensate for the low vacuum.
b) If vacuum is low, check piping, relief valves (if any) and seals in the filter system. Repair where necessary.

3) Excessive feed rate

a) Check solids yield on filter cloth
b) If excessive, reduce feed rate and chemical dosage rate accordingly

VI. Sludge Centrifugation

A. Process Evaluation Measures

Note: It is not possible to give exact procedures as to process evaluation without knowing the exact design intent. Normally in anaerobic sludge centrate quality is more significant than solid cake density.

1. Determine solids volume to be dewatered
2. Determine capacity of unit based on past experience if available
3. Evaluate capture vs. centrate quality

B. Problem Identification and Correction

1. Poor capture, cake density good
    a. Check pool depth if applicable and raise
    b. Lower feed rate if possible
    c. Add more polymer or evaluate other polymers for better capture
2. Cake density low, capture satisfactory
    a. Check pool depth. If high, lower until better density is obtained (if applicable)
    b. Vary dosage of polymer
    c. Consider increasing bowl speed
3. Low cake density, poor capture
    a. Check feed rate. It may be too high.
    b. Check polymer dosage, should clear up centrate
    c. Check pool depth, could be excessively high or low
4. Capture and cake density normal, but machine will not handle daily solids production
    a. Consider increasing flow to centrifuge and sacrifice centrate quality
    b. Check with manufacturer with regard to increasing bowl speed
    c. Increase aeration time
    d. Add chemicals
    e. Change speed ratio
    f. Check to see if characteristics of feed have changed

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 12: Solids Handling

Lesson 4: Tall Tales or "Where Did All That Sludge Come From?"

Lesson 4 of 5 lessons   Recommended Time: 40 minutes

Purpose: This lesson encourages trainees to share their experiences in troubleshooting solids handling problems by providing an opportunity for trainees to describe and discuss problems which they have seen. Trainees should be encouraged to surface problems which they may have encountered but for which they have no solution and to use class time to develop an approach to solving some of these problems.

Trainee Entry Level Behavior: Trainees should have achieved the learning objectives specified for Unit 12, Lesson 3 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. Describe actual solids handling problems which have been encountered in the field by trainees in the class and discuss how the *Process of Troubleshooting* was applied to solve the problems.
2. Given a trainee problem statement about an unsolved solids handling problem, apply the *Process of Troubleshooting* to develop an approach to solving the problem given.

Instructional Approach: Class discussion, questions and answers.

Lesson Schedule: The 40 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 15 minutes	Trainees Develop Problem Statement
15 - 40 minutes	Trainees Discuss Problems

Trainee Materials Used in Lesson: None

Instructor Materials Used In Lesson: Instructor Notebook, pages 12.4.1 - 12.4.3, Unit 12, lesson 4.

Instructor Materials Recommended for Development: None

Additional Instructor References: None

Classroom Set-Up: As specified in Unit 12, Lesson 1.

LESSON OUTLINE

I. Students Provide Problems (15 minutes)

   A. Instruct trainee work groups to prepare descriptions of one or two of the most extreme, most ludicrous sludge problems they have encountered. Each description should contain:

      1. Location of the problem

      2. Nature of the problem

      3. The type of plant

      4. Circumstances relating to the problem

      5. How the problem was handled and solved

   B. Allow groups 15 minutes to complete this portion of the exercise.

II. Class Discussion of Problems (25 minutes)

   A. Ask one work group to describe one of their problems.

   B. Allow for class questions, full discussion of problem.

   C. Toward end of discussion, ask class to suggest alternative approaches to the problem.

   D. Following discussion, select another group problem and repeat Steps A-C.

   E. If this session is going well, the instructor may choose to extend the time allocated by shortening Lesson 5, Unit 12.

KEY POINTS & INSTRUCTOR GUIDE

Note: Problems which have not been solved may be used with discussion directed toward how to develop a solution to the problem

Guide: Instructor is to serve as discussion leader allowing students full participation

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 5: Solids Handling

Lesson 5: Applying the Process of Troubleshooting

Lesson 5 of 5 lessons — Recommended Time: 40 minutes

Purpose: The unit operations and processes divisions used to structure the course *Troubleshooting O & M Problems in Wastewater Treatment Facilities* tends to focus trainee attention to a small portion of the plant as the site of problem occurrence and its effects on the treatment plant. This problem illustrates how a solids handling problem can cause difficulties in the liquid processing units (activated sludge units). The cause of the problem and its solution are remote from the indicators of the problem given to the class. The problem causes the trainees to view the entire treatment plant as one integrated system where a malfunction in one part of the system may affect all other parts of the system.

Trainee Entry Level Behavior: Trainees should have achieved the learning objectives specified for Unit 12, Lesson 4 before beginning this lesson.

Training Learning Objectives: At the conclusion of this lesson, the trainee should be able to:

1. Demonstrate his/her ability to apply the *Process of Troubleshooting* to analyze and solve a vacuum filtration solids handling problem which has deteriorated to the point that the entire plant has been affected.

2. Describe why a wastewater treatment plant must be viewed as an integrated system of component processes and operations and cite one example of how a malfunction in one part of the plant can affect other operations and processes in the plant.

Instructional Approach: Trainee problem solving with trainees role playing troubleshooters while the instructor role plays the operator.

Lesson Schedule: The 40 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 10 minutes	Introduce the Problem
10 - 30 minutes	Trainees Solve Problem
30 - 40 minutes	Discussion

Trainee Materials Used in Lesson: Trainee Notebook, page T12.5.1, "References."

Instructor Materials Used in Lesson: *Instructor Notebook*, pages 12.5.1 - 12.5. , Unit 12, Lesson 5.

Instructor Materials Recommended for Development: None

Additional Instructor References: None

Classroom Set-Up: As specified for Unit 12, Lesson 1.

LESSON OUTLINE

KEY POINTS &
INSTRUCTOR GUIDE

The problem presented begins by stressing difficulty with the activated sludge units. "Bulking" is reported. The sludge is not a true bulking sludge but rather the system has become glutted with solids. The primary clarifier units and aeration basins are overloaded with solids. Oxygen transfer capacity has been exceeded. The system has gone septic.

During the initial part of the problem the instructor should role play the operator and try to focus attention on the activated sludge process problems. Let the class work toward identifying the cause as a solids handling deficiency.

About six months ago the vacuum filter cloth was changed. No leaf tests were run. With the new cloth, filter yields dropped about 50% and cake moisture increased (dry solids concentration fell from 25% to less than 12%). Incinerator fuel costs increased by about 350%.

Vacuum filter operations were increased from 8 hours per day (one shift) to 16 hours per day (two shift operation). By operating a double shift on solids handling units the plant was kept in reasonably good shape.

However, after two months of double shift operation the Director of Public Works ordered the Chief Operator to drop the second shift because costs were out of hand. The Director of Public Works position was that the plant hadn't needed a double shift in solids handling before and shouldn't need one now since influent loadings had not changed.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	After futile arguments, the Chief Operator complied. With single shift operation in the solids handling division, the solids handling units couldn't keep up with solids production. Thus, solids began to accumulate in the system. First the primary clarifier filled with solids and became septic. The septic primary glutted with solids overloaded the aeration system with accumulated solids and increased organic load. Aeration capacity was exceeded. The whole system became septic. The final clarifiers couldn't handle the increased load. Hence solids accumulated in the final clarifiers, the finals became septic and floating septic sludge began overflowing the weirs. Final effluent, which had been well within the 20/20 standard on the plant, deteriorated until both BOD and TSS exceeded 100 mg/l. Throughout the problem, the instructor role plays the operator. Ad lib plant process data as appropriate to reflect the deteriorating plant conditions.
I. Case Study Problem for Class to Analyse Utilizing the Process of Troubleshooting (25 minutes)	Guide: Instructor presents this problem to the class in the role of "plant operator." The class should approach the problem as the "troubleshooters".
A. First Stage of Problem	
1. Operator (instructor reads to class)	
"I'm the chief operator of a 10 MGD activated sludge plant. We never had	The plant's about three years old. It has always performed well producing

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
any big problems until now. The plant incinerates sludge. The primary and waste activated sludge is dewatered with a vacuum filtration system."	good effluent, less than 20 mg/l BOD and 20 mg/l TSS.
"Until recently everything was OK. Last week I noticed bulking of my sludge, and the BOD in the effluent went way up. Now the whole activated sludge system seems to have gone to pot. The effluent is black, it smells like H---, and the solids are up over 100 mg/l."	Emphasize that there was never any serious problems at the plant until about six months ago.
2. Have class attempt to "troubleshoot" by asking questions of the "operator." The instructor should answer questions in accord with the information provided below.	Try to keep class focused on activated sludge problems. Lead class toward inability to waste solids because of inadequate solids handling capacity as the cause of the problem. Have class continue troubleshooting. Answer questions but don't go on with voluntary information unless the class gets "hung-up".
3. After discussion of situation, present the next stage of information about the problem.	
B. Second Stage of Problem	
1. Operator (read to class)	
"About six months ago, we replaced the media on the vacuum filter with a new type of media. We didn't have time to run any leaf tests to see how the sludge dewatered. What happened was we got a low filter yield and a higher moisture content in our sludge. Finally, the filter runs took so long that we needed to put on an extra shift. Not only that, but our fuel cost went up 350%!"	About 50% reduction in filter yield and a decrease in dry solids from about 25% to about 12%.
2. Have class use the steps in the Process of Troubleshooting to advise the operator on what he should have done at that time.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
3. After discussion, present the final stage of information about the problem.	
D. Final Stage of Problem	
1. Operator (read to class)	
"Well, that's it. Now you're here to help me turn this around. Since the activated sludge system worked so well in the past, we didn't try to change anything this time. No, we didn't increase the air or try to increase the cell mass in the system. I know, now we have bulking, lousy BOD removal and would you believe that we have 10 mg/l of sulfide in the final effluent? Our tertiary filters are plugged. The whole plant is damn near dead! Help!!	
2. Have class advise operator on what to do at this point.	
E. Analysis of Problem	
1. Have class discuss the key points illustrated in this problem, which are:	Guide: These are the key points of this problem and should be stressed
a. The entire plant failed because of an arbitrary decision to make one change in the sludge dewatering system.	Stress system interactions in wastewater treatment operations
b. That decision could have been avoided by testing the sludge dewatering properties with the new filter cloth using a leaf test.	
c. Once the sludge handling system failed, the primary and secondary systems were not controlled to	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
adjust to the changes. While it may have been too late to avoid the problem, the disastrous consequences could have been delayed with some smart process controls.	

II. Summary and Questions (15 minutes)

Use the remaining time to:

A. Briefly summarize the Solids Handling lesson.

B. Take questions and comments.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 12: Solids Handling

Lesson 5: Applying the Process of Troubleshooting

Trainee Notebook Contents

References T12.5.1

1381

REFERENCES

1. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA 430/9-78-001, U. S. Environmental Protection Agency, Municipal Operations Branch, Washington, D.C.

2. Gould, Robert F., ed., Anaerobic Biological Treatment Processes, A.C.S., *Advances in Chemistry Series* (1971).

3. McCarty, Perry L., Anaerobic Waste Treatment Fundamentals, *Public Works Magazine*, Series of four articles (Sept. thru Dec., 1964).

4. *Operations Manual Sludge Handling and Conditioning*, EPA 430/9-78-002, U.S. Environmental Protection Agency, Municipal Operations Branch, Washington, D.C. (February, 1978).

5. *Process Design Manual, Sludge Treatment and Disposal*, U.S. Environmental Protection Agency, Technology Transfer, Cincinnati, Ohio (October, 1974).

6. Zickefoose, C., and Hayes, R., *Operations Manual, Anaerobic Sludge Digestion*, STRAAM, Inc., U.S. Environmental Protection Agency, Washington, D.C. (February, 1976).

7. *Process Design Manual, Solids Handling and Disposal*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (September, 1979).

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 13: Land Treatment

Unit 13 of 15 Units of Instruction

Lessons in Unit: 2 Recommended Time: 2 hours

Instructor Overview of the Unit

Rationale for the Unit: Land application of secondary treatment effluents and land disposal of wastewater treatment sludges are becoming increasingly popular as a means of ultimate disposal. This unit briefly reviews the major considerations in land application of wastewaters and sludges and presents information about common operational problems encountered in land application systems.

Trainee Entry Level Behavior: The trainee should have completed Unit of Instruction 2, *Elements of Troubleshooting* before beginning this Unit.

Trainee Learning Objectives: At the conclusion of this Unit, the trainee should be able to:

1. Identify and describe the four major elements of land treatment systems.
2. Describe the degree of treatment of wastewater effluents needed prior to land application.
3. List the constituents of sludge that may cause problems with land disposal.
4. List the important factors in the transportation of wastewater effluents and sludge for land application.
5. Identify the types of wastewater distribution systems and the advantages and disadvantages of each.
6. List the points for consideration in the application of sludge to land areas.
7. Describe key soil and crop considerations for land disposal of sludge.
8. Identify the three most important factors in establishing land application sites for wastewater effluents.

9. Recognize the importance of monitoring surface and subsurface runoff quality.

10. Recognize common operational problems in the application of wastewater effluents to land treatment areas.

11. Determine the likely causes of operational problems for land treatment areas.

12. Evaluate his/her responses to land application problems in relation to the causes of the problems provided by the instructors.

13. Identify specific causes to land treatment problems.

Sequencing and Pre-Course Preparation for the Unit: This unit of instruction is presented in two lessons:

Lesson 1: Land Treatment Systems

Recommended Time: 75 minutes

Purpose: This lesson presents the fundamentals of land treatment systems for sludge and wastewater effluents and discusses those aspects of land treatment design and operation which either lead to good performance or to operational problems.

Training Facilities:

1. Large room, preferably 40' x 40', set in "herring bone" or "U" shape, with table and chair seating for 32 trainees.
2. Instructor table with lectern.
3. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.
4. Easel with pad.
5. 35mm carousel projector with remote control changer at instructor table.
6. At least four empty carousel trays.
7. Overhead projector.
8. Chalk, felt-tip markers, erasers, etc.
9. Six to eight chairs randomly spaced at back and sides of room for visitors.

1384

Pre-Course Preparation:

1. Trainee texts

   a. Order and have available at each trainee seating position *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA 430/9-78-001, Municipal Operations Branch, U. S. Environmental Protection Agency, Washington, D.C. (January, 1978).

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

   a. *Trainee Notebook*, page T13.1.1, "Application Rates of Wastewater Effluents to Land Areas."

3. Trainee Handout materials

   Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plans.

   a. None required for Lesson 1.

Instructional Approach: Illustrated lecture with class discussion.

Lesson 2: Troubleshooting Operational Problems

Recommended Time: 45 minutes

Purpose: This lesson looks at operational problems that occur in the operation of land treatment systems for wastewater effluents and provides an opportunity for discussion of the causes of operational problems on the land application of wastewater effluents.

Training Facilities: As specified for Lesson 1.

Pre-Course Preparation:

1. Trainee texts

   a. As specified for Lesson 1

2. *Trainee Notebook* materials

   Reproduce and insert into the *Trainee Notebook* the following:

a. *Trainee Notebook*, pages T13.2.1 - T13.2.8, "Troubleshooting Guide - Land Treatment."

b. *Trainee Notebook*, pages T13.2.9 - T13.2.10, "References."

3. Instructor Handout materials

Reproduce the following pages from the *Instructor Notebook* and have them available for distribution to the trainees when called for in the lesson plans.

a. None required for Lesson 2.

Instructional Approach: Trainee problem solving and discussion of findings.

Presentation Options for Course Director: The unit on *Land Treatment* is included for those areas of the country where land treatment of wastewater effluents and land disposal of sludge are common. In areas where these practices are not common, this unit should probably be excluded from the course.

The two-hour time period for this unit is adequate compared to a total course elngth of 28 to 40 hours. If desired, the unit could be shortened by reducing the presentation time for Lesson 1, and even by eliminating Lesson 2 if the Course Director is seeking to present only a brief overview of the subject.

If, for any reason, it is desired to lengthen this Unit, it would probably be desirable for the Course Director to obtain additional material geared specifically to the location where the course is being presented.

Some of the specific presentation options are as follows.

Lesson 1: *Land Treatment Systems*
This lesson is 1 hour, 15 minutes, and presents the basic elements of land treatment systems for wastewater renovation and for sludge disposal. This lesson may be easily shortened or lengthened by deleting some of the existing content or by adding additional material, depending on the degree of emphasis the Course Director wishes to place on this lesson.

Lesson 2: *Troubleshooting Operational Problems*
In lesson 2 the students work in groups to identify the causes of operational problems and these problems are discussed by the class. If the Course Director desires to retain a troubleshooting orientation for this lesson, then this lesson should be presented as is.

Summary of Unit of Instruction 13: Land Treatment

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
1. Land Treatment Systems 75 minutes	1. Identify elements of land treatment systems	1. Similarity of effluent and sludge application	1. Instructor to follow lesson outline	1. Slides 179.2/13.1.1 179.2/13.1.40
	2. Describe prior treatment requirements	2. Need for effective prior treatment	2. Use of word and picture slides and key	2. *Trainee Notebook*, page T13.1.1, "Application Rate of Wastewater"
	3. List the factors in transporting effluents and sludges	3. Importance of uniform distribution	3. Stimulate trainee discussion	3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 242-255 and 392-397
	4. Identify distribution systems	4. Monitoring of sludge prior to application	4. Importance of trainee questions	4. *Instructor Notebook*, pages 13.1.1 - 13.1.24
	5. Describe soil, crop and outflow considerations in land treatment	5. Need for monitoring outflow		
2. Troubleshooting Operational Problems 45 minutes	1. Recognize common land treatment problems	1. Four operational problems for trainee groups to identify causes	1. Trainees work in groups	1. Slides 179.2/13.2.1 179.2/13.2.12
	2. Determine alternative causes of problems	2. Causes of the following problems:	2. Instructor presents problem	2. *Instructor Notebook*, page 13.2.1 - 13.2.9

Summary of Unit of Instruction 13: Land Treatment (Continued)

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENTS	INSTRUCTOR'S APPROACH	MATERIALS
		a. Pooling of water b. Poor corn growth c. Broken pipes d. Soil erosion	with a brief description and slides	
	3. Evaluate responses to land application problems		3. Group has 5 minutes to identify the causes to each problem	3. "Troubleshooting Guide on Land Treatment", *Trainee Notebook* pages T13.2.1 - T13.2.8
	4. Identify specific causes to land treatment problems		4. Trainees present their answers to problems	4. *Trainee Notebook*, pages T13.2.9 - T13.2.10, "References"
			5. Instructor stimulates class discussion	

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 13: Land Treatment

Lesson 1: Land Treatment Systems

Lesson 1 of 2 lessons　　Recommended Time: 75 minutes

Purpose: This lesson presents the fundamentals of land treatment systems for sludge and wastewater effluents and discusses those aspects of land treatment design and operation which either lead to good performance or to operational problems.

Trainee Entry Level Behavior: The trainee should have completed Unit of Instruction 2, *Elements of Troubleshooting* before beginning this unit.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. Identify and describe the four major elements of land treatment systems.
2. Describe the degree of treatment of wastewater effluents needed prior to land application.
3. List the constituents of sludge that may cause problems with land disposal.
4. List the important factors in the transportation of wastewater effluents and sludge for land application.
5. Identify the types of wastewater distribution systems and the advantages and disadvantages of each.
6. List the points for consideration in the application of sludge to land areas.
7. Describe key soil and crop considerations for land disposal of sludge.
8. Identify the three most important factors in establishing land application sites for wastewater effluents.
9. Recognize the importance of monitoring surface and subsurface runoff quality.

1391

Instructional Approach: Illustrated lecture with class discussion.

Lesson Schedule: The 75 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 5 minutes	Introduction to Land Treatment
5 - 15 minutes	Prior Treatment
15 - 25 minutes	Transportation of Sludge and Effluent
25 - 45 minutes	Distribution of Sludge and Effluent
45 - 70 minutes	The Land Area
70 - 75 minutes	Summary and Questions

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, page T13.1.1, "Application Rates of Wastewater Effluents to Land Areas."
2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*
    a. Land Treatment, pages 242-255.
    b. Application of Sludges to Land, pages 392-397.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 13.1.1 - 13.1.24, Unit 13, Lesson 1.
2. Slides 179.2/13.1.1 - 179.2/13.1.40.

Instructor Materials Recommended for Development: The instructor should develop and incorporate into the lesson information about local and state specific guidelines and regulations concerning land application of wastewaters or sludges.

Additional Instructor References:

1. Metcalf and Eddy, Inc., *Wastewater Engineering Treatment Disposal Reuse*, pages 760-824, McGraw-Hill Book Company, New York (1979).
2. *Process Design Manual Sludge Treatment and Disposal*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (September, 1979).
3. *Sludge Treatment and Disposal. Process Design Manual*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio, (October, 1974).

4. *Land Application of Sewage Effluents and Sludges: Selected Abstracts*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (June, 1974).

5. "Recycling Municipal Sludges and Effluents on Land," National Association of State Universities and Land-Grant Colleges, July, 1973.

6. *Costs of Wastewater Treatment by Land Application*, Office of Water Program Operations, U. S. Environmental Protection Agency, Washington, D.C. (June, 1975).

7. Sopper, W. E. and Kardos, L. T., Editors, *Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland*, in Symposium Proceedings at University Park, PA, The Pennsylvania State University Press, August, 1973, 479 pages.

8. Pound, C. E. and Crites, R. W., *Wastewater Treatment and Reuse by Land Application*, Volumes I and II, U. S. Environmental Protection Agency, Washington, D.C. (August, 1973).

9. Kardos, L. T., et al, *Renovation of Secondary Effluent for Reuse as a Water Resource*, EPA-660/2-74-016, U. S. Environmental Protection Agency, Office of Research, Cincinnati, Ohio (February, 1974).

10. Myers, Earl A., "Management of Land Disposal Systems for Adequate Renovation," AIChE Conference Proceedings, Chicago, Illinois (May, 1975).

11. Sullivan, R. H., Cohn, M. M., and Baxter, S. S., *Survey of Facilities Using Land Application of Wastewater*, American Public Works Association, U. S. Environmental Protection Agency, Washington, D.C. (July, 1974).

12. Butler, Robert M. et al, *Spray Irrigation Disposal of Wastewater*, Sp. Circ. 185, Ag. Ext. Soc., The Pennsylvania State University, University Park, PA (1974).

13. Myers, Earl A. and Burt, Edward A., "Automation of Wastewater Land Application Systems," Sprinkler Irrigation Association Conference Proceedings, Atlanta, Georgia (February, 1975).

14. Malhotra, Sudarshan K. and Myers, Earl A., "Design, Operation and Monitoring of Municipal Land Irrigation Systems in Michigan," WPCF Conference, Denver, Colorado (October, 1974).

15. *Process Design Manual Municipal Sludge Landfills*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (October, 1978).

16. *Operation of Wastewater Treatment Plants, MOP 11*, pages 359-380, Water Pollution Control Federation, Washington, D.C. (1973).

Classroom Set-Up:

1. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees.

2. Instructor table with lectern.

3. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.

4. Easel with pad.

5. 35mm carousel with remote control changer at instructor table.

6. At least four empty carousel trays.

7. Overhead projector.

8. Chalk, felt-tip markers, erasers, etc.

9. Six to eight chairs randomly spaced at back and sides of room for visitors.

LESSON OUTLINE

I. Introduction to Land Treatment (5 minutes)

A. Uses of Land Treatment

1. Widely used for disposal of sludge, primarily from small treatment plants in agricultural areas.
2. In several areas of the country, it is used for treatment of waste effluents.
3. Crop production and land reclamation may be very important secondary purposes of land treatment - however, the primary purposes are effluent treatment and sludge disposal.

B. Troubleshooting Land Treatment

1. Many operating principles are the same for land treatment of effluents and sludge.
2. Many problems are similar; therefore, troubleshooting approaches are similar.
3. This lesson is applicable to both effluent and sludge treatment although most of the material was originally prepared to pertain to effluents.

C. Land Treatment Systems

1. Effluent treatment systems and sludge disposal systems have four common elements
    a. Prior treatment at a treatment site.
    b. Transportation to a site.
    c. Distribution over a land area.
    d. The land area itself.

KEY POINTS & INSTRUCTOR GUIDES

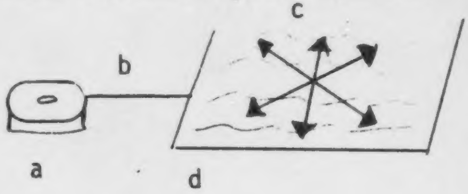
Use Slide 179.2/13.1.1
Slide 179.2/13.1.1 is a blank.

Refer class to *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 242-255 and 392-297.

Key Point: Similarity of effluent and sludge treatment systems.

Use Slide 179.2/13.1.2
Slide 179.2/13.1.2 is a schematic

"Land Treatment System Elements



LESSON OUTLINE

2. Each element shown in slide can create problems in the effectiveness of land treatment and thus must be looked at in order to troubleshoot land treatment systems.

3. This lesson will look at each of these elements in detail - first from an operations point of view and then from a troubleshooting perspective.

II. Prior Treatment of Waste Effluents and Sludge (10 minutes)

A. Purpose of Land Treatment as a Part of an Overall Waste Treatment System

1. Conceivably, any effluent can be applied to land.

2. Untreated sewage causes odor nuisance, health hazards, therefore not presently acceptable to apply to land areas.

3. Treatment of secondary effluent - removal by land treatment system provides excellent advanced waste treatment and removals.

4. Therefore, most systems in use, and in the future, will be for the final polishing of secondary effluents.

B. Secondary Treatment Prior to Land Application

1. Oxidation ponds normally used because:

a. They are most economical for small systems.

b. They provide winter storage which is absolutely necessary for land treatment systems.

c. Land is usually available.

2. Disadvantages of oxidation ponds

KEY POINTS & INSTRUCTOR GUIDES

Key Point: Effective treatment is necessary in order to make land treatment feasible under current standards.

LESSON OUTLINE

a. Too much land needed for large systems - over 5,000 people.

b. Cold climates limit BOD loadings.

3. Other secondary processes are needed for larger systems, including:

   a. Anaerobic cell and faculative ponds.

   b. Mechanical aeration - more costly.

C. Effluent Storage

1. Normal Irrigation Season: 26-30 weeks per year, therefore storage is needed. Depends on climate.

2. Fill and draw oxidation ponds excellent for storage.

3. Many ponds have 3 cells with piping flexibility for series and parallel operation.

D. Expected Quality of Secondary Treatment Effluent - Land Treatment Influent

1. Review typical characteristics of effluent used for land treatment.

2. Quality of land treatment influent must be monitored during operations and should be analyzed as part of troubleshooting.

E. Purpose of Land Application of Sludge

1. To dispose of sludge more efficiently and less costly than by other methods in a manner not creating other environmental problems.

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/13.1.3

Slide 179.2/13.1.3 is a word slide which reads:

"Expected Quality - Land Treatment Influent

pH	7.5-9.2
5 day BOD	2-30 mg/l
DO	7-11 mg/l
SS	5-100 mg/l
NH_3-N	0.7-5 mg/l
NO_3-N	0.1-2 mg/l
Organic N	5-15 mg/l
Total P	2-7 mg/l"

Use Slide 179.2/13.1.4

Slide 179.2/13.1.4 is a word slide which reads:

"Land Application of Sludge Purposes by Order of Priority

LESSON OUTLINE

2. To use as a soil conditioner and fertilizer for the production of crops. (The value of sludge as a fertilizer is questionable.)

3. To use as part of a land reclamation effort

4. It is very important that the purpose of land application of sludge is kept in the proper perspective.

F. Prior Treatment of Sludge

1. Sludge should be stabilized, need not be dewatered.

2. Use Slide 179.2/13.1.5 to summarize concerns about applying sludge to farm land.

3. Removing industrial wastes must be done at the source. There is no way of removing metals from sludge at a treatment plant.

4. Pathogens are undesirable due to possible exposure.

   a. Can be destroyed by storage, pasteurization, lime application, chlorine, other chemicals.

   b. Survival of pathogens depends on organism, temperature, moisture, soil, organic matter present.

5. Metals content in sludges

   Typical concentrations: dry basis

Zinc	1,500 - 10,000 mg/l
Copper	700 - 6,000 mg/l
Nickel	200 - 600 mg/l
Cadmium	40 - 800 mg/l

III. Transportation of Sludge and Waste Effluents (10 minutes)

KEY POINTS & INSTRUCTOR GUIDES

1. To Dispose of Sludge:
   Efficiently
   Less Costly Than Other Methods
   Environmentally Sound
2. Soil Conditioner To Raise Crops
3. Land Reclamation"

Use Slide 179.2/13.1.5

Slide 179.2/13.1.5 is a word slide which reads:

"Concerns About Sludge Content in Applying Sludge to Land

Industrial Waste Residues, Primarily Metals
Metals Can Also Be Present In Domestic Wastes
Pathogenic Organisms"

Refer class to local or state guide lines and regulations affecting land application of wastewater or sludges.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
A. Transportation of Sludge	
1. Cost factor usually determines method of transportation.	
2. Methods: tank truck, barge, rail, pipeline.	
3. For small communities with land available, trucks afford greatest flexibility.	
4. Retention capacity at plant or site can make transportation flow more even, handle sludge when it is not being spread.	
B. Troubleshooters will probably have the greatest opportunity to provide assistance to small communities, where sludge is transported by truck as shown in the following slides.	
1. Trucks are more maneuverable than pipelines. This one has a vacuum pump to get the sludge or scum into the tank, gravity to let it out.	Use Slide 179.2/13.1.6 Slide 179.2/13.1.6 is a photograph showing a typical tank truck used to haul liquid waste or liquid sludges to land treatment areas.
2. The previous view showed about a 1,600 gal. unit. This one carries about 3 times that amount.	Use Slide 179.2/13.1.7 Slide 179.2/13.1.7 is a photograph showing a major facility for filling trucks to haul liquid waste or liquid sludge to land treatment areas.
3. Another tank hauling unit. Note the spreader outlet and tire support. A low tire loading factor is advisable for field application.	Use Slide 179.2/13.1.8 Slide 179.2/13.1.8 is a photograph showing a large truck used to haul liquid sludges.
4. One tank loading piping hookup is shown in this view. Protection from overfilling better be good to avoid a messy cleanup or poor public relations.	Use Slide 179.2/13.1.9 Slide 179.2/13.1.9 is a photograph of a waste hauling truck being filled with liquid waste.
C. Transportation of Waste Effluents.	
1. Land treatment areas are generally close to the secondary treatment plant unlike some sludge disposal areas.	

LESSON OUTLINE

2. Pipelines are generally used.
3. The key to transportation of waste effluents is adequate pumping to maintain adequate flows and pressure in wastewater irrigation distribution systems.
4. Canals may be used in some areas where flood irrigation methods are used.

D. Importance of Proper Control Over Pumping System for Waste Effluents

1. Proper flow is key to adequate distribution which in turn is key to maximum renovation of wastewater.
2. Pressure is key to flow.
3. Improper flows and pressures can damage system as well as create distribution problems.

E. To provide control over pumping system, the following means are used.

1. Flow meters - measures rate of flow in gpm
   a. Use from station to station to measure variations and balance in flows.
   b. Flow rate too high - can break lateral or riser.
   c. Flow rate too low - can clog nozzles.
   d. Daily records of flow volumes represent a permanent record over entire irrigation system.
2. Automatic Pressure Recorders
   a. Provides available, visual and continuous record throughout the system.
   b. Pressure plus flow records - valuable for system evaluation and troubleshooting.

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/13.1.10
Slide 179.2/13.1.10 is a word slide which reads:

"Control Over Waste Effluent
Pumping Systems

Distribution is Key to Effective Wastewater Renovation
Flow is Key to Distribution
Pressure is Key to Flow
Improper Flows Damage System"

Use Slide 179.2/13.1.11
Slide 179.2/13.1.11 is a word slide which reads:

"Control Pumping Systems By

Flow Meters
Automatic Pressure Recorders
Inflow Automatic Sampler
Pressure Relief Valve
Automatic Shutoff for High Partial Vacuum"

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDES

c. High and low pressure signaling attachments - provides continuous information necessary to assure uniform distribution.

3. Automatic Sampler for Influent - provides records of quality of wastewater inflows.

4. Pressure Relief Valve

   a. Protects system if line valves do not open.

   b. Handles flows as additional pumps come on line.

   c. Protects against water hammer and air shock loads.

5. High Partial Vacuum Automatic Shutoff

   a. Protects pumps against excessive partial vacuum at inlet.

   b. High vacuum causes pump cavitation.

   c. Condition can be caused by clogging of pump screen.

IV. Distribution of Waste Effluents and Sludge (20 minutes)

The wastewater distribution system is an important determinant in the quality of wastewater renovation at a treatment site and on crop growth.

Refer class to page 244, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* for illustration of system.

A. General Factors of Wastewater Distribution

1. Importance of uniformity of distribution.

Key Point: Uniformity of distribution.

   a. There should be less than 10% variation across receiving area.

   b. Creates best renovation of wastewater and crop growth.

2. Most systems - distribution pattern needs to be measured physically on the actual land area.

LESSON OUTLINE

3. There are three principal types of distribution:
    a. Flood irrigation
    b. Spray irrigation
    c. Ridge and furrow application

B. Flood Irrigation

1. Advantages
    a. No wind drift, therefore little border or buffer area is needed.
    b. Some states do not require chlorination.
    c. Some areas can be flooded by gravity, therefore no pumping and electrical costs.
2. Disadvantages
    a. Obtaining uniformity of distribution.
    b. Difficulty of automating.
    c. Difficult to maintain proper field grades.

C. Spray Irrigation

1. Most common form of land application of waste effluents.
2. Importance of system pressure - with uniform sprinkler size, flow rate is a function of pressure.
    a. Therefore, to control or troubleshoot system, monitor pressure.

KEY POINTS & INSTRUCTOR GUIDES

Guide: Illustrate this section with the following slides.

Use Slide 179.2/13.1.12

Slide 179.2/13.1.12 is a word slide which reads:

"Flood Irrigation

Advantages	Disadvantages
No Wind Drift	Flow Uniformity
No Chlorination Some States	Difficult to Automate
Flood by Gravity - Low Cost	Difficult to Maintain Grades"

Key Point: The importance of proper pressure in a spray irrigation system.

b. 20% pressure difference causes a 10% flow difference.

c. Pressure gauges with Pitot tube adaptors provide rapid field evaluation of the distribution system.

3. Portable Aluminum Spray Irrigation Systems

a. Usually used as auxiliary equipment for special areas.

b. Used for small areas.

4. Traveler Systems

a. Low initial cost, flexibility of areas that can be irrigated.

b. Can distribute wastewater with large solids particles.

c. Disadvantages:

1) Take much labor
2) Difficult to automate
3) Produce much wind drift

5. Center Pivots

a. Relatively low operating cost.

b. Low capital cost compared to solid set systems.

c. Difficult to operate in very wet and muddy conditions.

d. Appreciable amount of exposed equipment.

e. Requires circular farming pattern - or cannot irrigate entire rectangular field.

6. Solid Set Spray Irrigation System

a. Can be rigged to accommodate shape of field.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
b. Can be set up more quickly than center pivot rig - for any time of year.	
D. Slides on Wastewater Distribution	Guide: The following slides show different wastewater distribution systems.
1. Portable pipe can be used for small systems but frequently require much labor and cause management and operational problems.	Use Slide 179.2/13.1.13 Slide 179.2/13.1.13 is a photograph showing piping near a land treatment site awaiting installation.
2. This buried, solid-set system saves the labor and reduces the management problems.	Use Slide 179.2/13.1.14 Slide 179.2/13.1.14 is a photograph showing a spray irrigation site where corn is being cropped.
3. Especially when the valves are automatically changed by a controller.	Use Slide 179.2/13.1.15 Slide 179.2/13.1.15 is a photograph showing an automatic pump control in a spray irrigation field.
4. Center pivot systems can cover up to 200 acres in one circle.	Use Slide 179.2/13.1.16 Slide 179.2/13.1.16 is a photograph showing a center pivot spray irrigation system.
5. Self-propelled travelers have the advantage of economy and the ability to distribute liquids with large solids.	Use Slide 179.2/13.1.17 Slide 179.2/13.1.17 is a photograph showing a self-propelled spray irrigation rig.
6. Self-propelled, however, means different things to different people. Some people did not like the idea of us using these on airport grass runways.	Use Slide 179.2/13.1.18 Slide 179.2/13.1.18 is a cartoon which shows a woman on a telephone talking to husband watching T.V. and the caption reads, "Ed, Renker says our self-propelled sprinkler is wandering around in his hay field."
7. In reality, they follow a very well-defined path and can be used many places that center pivots cannot..between roads and beside trees.	Use Slide 179.2/13.1.19 Slide 179.2/13.1.19 is a photograph of a aerial view of a spray irrigation site showing the travelling action of a self-propelled spray irrigation rig.

LESSON OUTLINE

8. When debris content is great and particle size is large, remove the screens and use a large nozzle. Or use a self-cleaning screen back at the pumphouse.

9. For proper soils, flood irrigation has its place...

10. Also, so does irrigating with siphons, BUT usually not for irrigating wastewater year around.

E. Application Rates

1. Refer class to *Trainee Notebook*, page T13.1.1.

2. Discuss points on Slide 179.2/13.1.23 and review criteria in *Trainee Notebook*.

F. Drainage

1. Drainage is a critical aspect of system management.

2. Preferred procedure - install good surface drainage on irrigated area which will

   a. Dispose of snow melt, interflow, natural precipitation.

   b. Keep maximum soil - water capacity for renovating wastewater.

3. Drainage depends on site, soil and groundwater conditions

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/13.1.20
Slide 179.2/13.1.20 is a photograph showing the spray nozzle on a waste treatment spray irrigation system.

Use Slide 179.2/13.1.21
Slide 179.2/13.1.21 is a photograph showing a flood irrigation waste treatment site.

Use Slide 179.2/13.1.22
Slide 179.2/13.1.22 is a photograph showing a siphon type flood irrigation system.

Guide: Use the following word slides to discuss the importance of application rates.

Use Slide 179.2/13.1.23
Slide 179.2/13.1.23 is a word slide which reads:

"Application Rate - An Important Variable for

Renovation of Wastewater
Romoval of Effluent Constituents
Crop Success
Drainage
Erosion"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
a. Some can be drained economically.	
b. Some areas with high clay content soils can't be properly drained economically.	
G. Application of Sludge	
1. Ridge and furrow method - level land and cold climates.	
2. Spray irrigation - more flexible, need less soil preparation.	
3. Rates - can vary from 0.5 to 100 tons per acre.	
4. To support crop nitrogen needs - usually 5 to 10 tons per acre of liquid digested sludge.	
5. Points for consideration or monitoring during sludge application:	Key Point: Sludge must be monitored during application to land.
a. Trace element composition of sludge application.	
b. Nitrogen content of sludge, soil and crops and potential for nitrate pollution to groundwater.	
c. Use of only disinfected sludge on low growing fruits and vegetables.	
d. Hydraulic overloading of soil.	
e. Ultimate use of the land.	
f. Runoff and erosion control practices.	
6. Slides on sludge application	
a. This view shows a simple outlet device for the previously shown tanker. The extra flexible tubes are for hookup to onsite storage such as for piped sludge applicators.	Use Slide 179.2/13.1.24 Slide 179.2/13.1.24 is a photograph with a close-up view of the discharge from a liquid sludge hauling truck (big wheels).

LESSON OUTLINE

b. Another sludge spreader device. The sludge must have floated in the tank as this is mostly water. If anaerobic sludge isn't degassed, it tends to float. The sludge will appear later. There are at least as many options for sludge spreading as for trickling filter nozzles. As long as they are workable, they may be used.

c. Spreading sludge on a cover crop area or forest land has to be limited to acceptable rates. A high application rate needs to be worked in to avoid odor nuisances. It also provides better soil conditioning.

V. The Land Area - For Sludge Disposal and Wastewater Renovation (25 minutes)

A. Soil Considerations for Sludge Disposal

1. Soil properties to consider for sludge assimilation:

a. Depth

b. High infiltration and percolation capacity

c. Fine texture for water and nutrient holding capacity

d. Good drainability and aeration

e. Neutral or alkaline pH

2. Fertilizer properties

a. Half of nitrogen and potassium is in liquid phase, therefore, is lost upon drying or dewatering.

b. Potassium to N or P ratio is low, therefore, there is not enough potassium if sludge application rate is designed to serve nitrogen needs.

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/13.1.25
Slide 179.2/13.1.25 is a photograph showing a big wheel waste application truck in operation.

Use Slide 179.2/13.1.26
Slide 179.2/13.1.26 is a photograph showing a tractor and disk being used to disk in the applied waste.

Key Point: Nutrient properties of sludge are critical to both crop growth and over fertilization.

Use Slide 179.2/13.1.27
Slide 179.2/13.1.27 is a word slide which reads:

"Fertilizer Properties of Sludge

Liquid Digested Sludge
  Nitrogen: 3.5 - 6.4%
  Phosphate: 1.8 - 8.7%
  Potash: 0.24 - 0.84%
Limiting Factor - Nitrogen
Excess Nitrogen - Pollutes Groundwater, Damages Crops, Toxic to Animals"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES

c. Primary nutrient content - liquid digested sludge, 25% of dry weight.

Nitrogen: 3.5-6.4%
Phosphate: 1.8 - 8.7%
Potash: 0.24-0.84%

3. Nitrogen is generally the limiting factor on application

    a. Excess nitrogen pollutes groundwater with nitrates.

    b. High nitrogen content toxic to humans and animals.

    c. Can create excessive nitrates in crops.

    d. There is no "cookbook" determination as to the proper rate of sludge application to limit nitrates: soil type, geology, climate, crops and farm management are all factors that determine rate.

B. Crop Considerations

1. Crops vary widely in reaction to sludge enriched soils.

2. May be affected by trace elements and could concentrate such elements to inhibit future use.

3. Reaction of crops is generally site dependent.

C. Land Reclamation - Sludge can be used to reclaim strip mines and other disturbed land surfaces.

1. High application rates commonly used can lead to water contamination without proper drainage controls.

2. Leachates may be treated before being discharged, as can surface runoff.

LESSON OUTLINE

3. Accumulation of sludge can lead to accumulation of trace elements.

4. Neutral pH minimizes toxicity.

D. Slides on Land Areas for Sludge Disposal

1. This chart of corn yield versus sludge application rate is self-explanatory. Sludge is a low grade fertilizer. It contains water, organic conditions, base exchange capacity, trace nutrients and more favorable soil structure. Certain excess metals and other damaging pollutants may be a problem unless controlled at the source.

2. This coal mine acid drainage area may be reconditioned by grading and sludge application.

3. This view of a graded mine spoil area was covered with 3 inches of sludge three years prior to this late summer view. The area to the right reseeded and supported good growth. The barren area to the left wasn't covered with sludge. Seeds falling on this area turned brown after contact with the highly acid soil.

4. The lush green of this field is the result of sludge treatment a year earlier. One crop of hay has been removed, another is on the way. The dark colored area in the background on either side of the green strip is sludge application area. As one Englishman phrased it - this means meat, bread and beer - a combination that is difficult to surpass.

E. Renovation of Wastewater on Land Areas

1. Above all, it must be remembered that the purpose of wastewater renovation is to obtain a high quality effluent.

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/13.1.28
Slide 179.2/13.1.28 is a chart:

Sludge Application vs. Corn Yield

Weekly Rate (inches/acre)	Total Applied (tons/acre)	Yield (bu/acre)
0"	0	33
1/4"	8.6	68
1/2"	17.0	63

Hanover Park, Illinois

Use Slide 179.2/13.1.29
Slide 179.2/13.1.29 is an aerial photograph showing sludge application being used in a strip mine reclamation area.

Use Slide 179.2/13.1.30
Slide 179.2/13.1.30 is a photograph showing good grass growth on the right side where sludge application has been used to reclaim a strip mined area as contrasted to no grass growth in an area to which sludge has not been applied.

Use Slide 179.2/13.1.31
Slide 179.2/13.1.31 is a photograph showing the grass cover on a strip mine reclamation mine area which has been treated with waste sludge.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
2. Site factors - There are three important site factors that need to be considered in establishing and operating wastewater renovation systems.	Use Slide 179.2/13.1.32 Slide 179.2/13.1.32 is a word slide which reads: "Key Site Factors for Wastewater Renovation Soils - Determine Design and Type of System Crops - Management of Crops Secondary to Wastewater Concerns Outflow - Only Indicator of Renovation Efficiency"
F. Soils - Variation in soils necessitates different design and operations for land application of wastewater.	
1. Soil Characteristics	
a. Sandy soil, deep water table, where extensive renovation not required, use flooding/infiltration - percolation.	
b. Tight clay soils - use overland flow grass filtration.	
c. Spray irrigation, if properly designed applicable to full range of soil conditions.	
d. Too much organic material in wastewater - can decrease infiltration and increase runoff.	
2. Erosion	Key Point: Soil erosion can be a major problem that occurs with land application of wastewater.
a. Easily eroded soils and slopes should be kept in grass cover.	
b. Mild slopes - use steps of grass and corn.	
c. Flat site - use corn crop year after year.	

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDES

d. Small area field trials useful to determine perferred procedure for any location.

G. Crops. Management of crops must be done in conjunction with the most appropriate wastewater treatment scheme and not necessarily for maximum crop production.

1. Quality of crops

   a. Often indicates good or poor trends.

   b. Crop killed by excessive water or constituents of wastewater can't properly function as a "living filter" for wastewater renovation.

   c. Corn problems - for example:

      1) Dark green - removing much nitrogen.

      2) Light yellow - insufficient nitrogen, or a drainage problem.

      3) Small stalks - drainage problem - water table, insufficient root growing area.

   d. Excesses of some elements prevent uptake in others.

2. Harvesting of crops

   a. Should be harvested and removed from area.

   b. Best to remove entire crop, i.e. - corn for silage rather than just the ears.

   c. Trees - less renovation, nutrients recycled with leaf fall.

   d. For nitrogen removal - leave organic matter on area as a carbon source.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDES

3. Farm and crop management

    a. Sound agricultural skills needed.

    b. Assistance available from Soil Conservation Service - wastewater treatment plant troubleshooters can't be expected to be experts in agriculture.

H. Outflow. Surface and subsurface quality are the only true indicators of renovation efficiency at a treatment site. Therefore, continual and permanent monitoring systems must be used and relied upon to understand the effectiveness of treatment.

Key Point: Need for monitoring of outflow.

1. Spray irrigation systems

    a. Designed so there is no direct runoff of wastewater.

    b. Snow melt and precipitation - should runoff freely.

    c. Underflow - should drain freely and meet quality standards.

    d. All runoff locations - should be monitored and a permanent record kept.

2. Overland flow systems

    a. Designed for wastewater to run over soil and away from site in surface channels.

    b. Removal of overland flow - suspended solids removed by grass filtration. 50% phosphorous removed by direct contact with soil and plants. Nitrogen by conversion to nitrogen gas.

    c. Local regulations and standards often determine type of irrigation system used.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
3. Underground flows	
a. Must still be monitored.	
b. Use buried tiles to remove renovated water at areas with well drained soils and high water tables.	
c. Deep wells or suction lysimeters used to monitor sites with deep water tables.	
4. Removal rates for well designed and managed spray irrigation systems	
a. Phosphorous - 90-95%	
b. Nitrogen - 70-90%	
c. Suspended Solids - nearly all removed in top four foot of soil.	
I. Slides on Wastewater Renovation Areas	
1. Monitoring systems should have been installed before irrigation was started. The monitoring data establish baseline	Use Slide 179.2/13.1.33 Slide 179.2/13.1.33 is a photograph showing a crew installing a ground water monitoring device.
2. Suction lysimeters frequently are used for monitoring the degree of renovation. These lysimeters should be tested for leaks before being installed.	Use Slide 179.2/13.1.34 Slide 179.2/13.1.34 is a photograph showing a technician reading a suction lysimeter.
3. A suction lysimeter installed in a check plot for comparing data obtained within the irrigated plots.	Use Slide 179.2/13.1.35 Slide 179.2/13.1.35 is a photograph showing a technician monitoring a suction lysimeter in a check plot which is not treated with wastewater.
4. The preferred procedure is to remove both stalk and ear for maximum removal of nutrients; that is, unless you need the stalk's organic matter as a carbon source.	Use Slide 179.2/13.1.36 Slide 179.2/13.1.36 is a photograph showing corn being harvested from a waste treatment site.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
5. A good grass cover reduces erosion. Also is a very good user of nitrogen (Reed Canarygrass).	Use Slide 179.2/13.1.37 Slide 179.2/13.1.37 is a photograph showing Reed Canarygrass which provides excellent ground cover against erosion.
6. In our evaluation and troubleshooting procedures we are always striving for good quality crops and a pleasing environment...both very helpful in public relations and just being good neighbors and a cost reducing element.	Use Slide 179.2/13.1.38 Slide 179.2/13.1.38 is a photograph showing a spray irrigation site adjacent to a working farm.
7. Example of good lagoon treatment and solid-set spray irrigation facility at Middleville, Michigan.	Use Slide 179.2/13.1.39 Slide 179.2/13.1.39 is a photograph showing an aerial view of the lagoon system used to store secondary effluent prior to plant application.
VI. Summary and Questions (5 minutes)	Use Slide 179.2/13.1.40 Slide 179.2/13.1.40 is a blank.
A. Briefly summarize key points in land treatment	
1. The importance of prior treatment and sludge handling.	
2. Transportation of sludge and waste effluents.	
3. Distribution.	
4. The land areas and factors which must be considered.	
B. Use remaining time for questions.	

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 13: Land Treatment

Lesson 1: Land Treatment Systems

Trainee Notebook Contents

Application Rates to Wastewater Effluents to Land Areas T13.1.1

Application Rates of Wastewater Effluents to Land Areas

1. Hydraulic Loadings
    a. Depends on infiltration capacity and conductivity of underlying geological materials.
    b. 1.5 to 4.5 inches per week, 26 to 30 weeks per year, normal rate
    c. Well drained sandy soils - can use over 3 inches per week.
    d. Design loading rates can't exceed vertical percolation rate and shouldn't create excessive buildup of groundwater.
2. Organic Loading
    a. Depends on soils, depth of groundwater, crop, type of system.
    b. Spray irrigation, normal loads of 100 to 500 pounds BOD per acre. per year.
    c. Seepage basins - normal loads of 400 to 1,600 lb BOD acre/year.
3. Nitrogen Loading
    a. Varies by nitrogen concentration and hydraulic loading rate.
    b. Penn State - 355 lb/acre/year yielded 97.3% removal.
    c. Normal variation, spray irrigation, 50 to 250 lb/acre/year.
    d. Seepage basins, normal variation, 150 to 650 lb/acre/year.
4. Phosphorous Loading
    a. Penn State - 99.2% removal at 133 lb/acre/year.
    b. Spray irrigation, normal rate, 40 to 125 lb/acre/year.
    c. Seepage basins, normal rate, 100 to 400 lb/acre/year.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 13: Land Treatment

Lesson 2: Troubleshooting Operational Problems

Lesson 2 of 2 lessons Recommended Time: 45 minutes

Purpose: This lesson looks at operational problems that occur in the operation of land treatment systems for wastewater effluents and provides an opportunity for discussion of the causes of operational problems on the land application of wastewater effluents.

Trainee Entry Level Behavior: The trainee should have completed Unit 13, Lesson 1, before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee should be able to:

1. Recognize common operational problems in the application of wastewater effluents to land treatment areas.
2. Determine the likely causes of operational problems for land treatment areas.
3. Evaluate his/her responses to land application problems in relation to the causes of the problems provided by the instructors.
4. Identify specific causes to land treatment problems.

Instructional Approach: Trainee problem solving and discussion of findings.

Lesson Schedule: The 45 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 2 minutes	Introduct Problem Solving Session
2 - 12 minutes	Problem 1: Pooling of Water
12 - 22 minutes	Problem 2: Poor Corn Crop
22 - 32 minutes	Problem 3: Broken Pipes
32 - 42 minutes	Problem 4: Erosion
42 - 45 minutes	Summary

1417

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T13.2.1 - T13.2.8 , "Troubleshooting Guide - Land Treatment."

2. *Trainee Notebook*, pages T13.2.9 - T13.2.10, "References."

3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*

   a. Pages 242-255, Land Treatment
   b. Pages 392-297, Application of Sludge to Land

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 13.2.1 - 13.2.9 , Unit 13, Lesson 2.

2. Slides 179.2/13.2.1 - 179.2/13.2.12.

Instructor Materials Recommended for Development: None

Additional Instructor References: As specified for Unit 13, Lesson 1.

Classroom Set-Up: As specified for Unit 13, Lesson 1.

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDES

The instructor presents four (4) land treatment problems to the students as follows:

1. Seat trainees in 4-person groups previously selected by the course director. Trainees need note paper to record their answers.
2. Each problem is allotted approximately 10 minutes as follows:

   1 minute - presentation by instructor using slides.
   4 minutes - analyses by trainee groups.
   5 minutes - discussion of trainee group findings

3. For each problem, the instructor is to show the designated slides according to the lesson plan outline from which the trainees are to identify the possible causes of the problem.
4. The instructor may answer questions as to the nature of the problem - or as to what each slide depicts.
5. Trainee participation and discussion within each group should be encouraged during the problem solution phase. Discussion between work groups should be encouraged during the reporting of findings phase.
6. After 10 minutes, the instructor must go on to the next problem.

I. Introduction to Problem Analysis (2 minutes)

Use Slide 179.2/13.2.1
Slide 179.2/13.2.1 is a blank.

   A. Make sure trainees are seated with their groups. They will need paper to record the answers to the problems being presented to them.

   B. Briefly review the instructions.

Guide: Use photograph slides to illustrate problems. Repeat slides as necessary for students during problem solving sections.

   C. Stress that you are looking for the trainees to apply the Process of Troubleshooting, by using a systematic approach to find possible

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
alternative causes to the problem presented.	
D. Stress that trainee participation and involvement is sought.	
E. Refer class to:	
1. *Trainee Notebook*, page T13.2.1.	
2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pages 252-255.	
II. Problem 1: Pooling of Water (10 minutes)	
A. Problem Statement	Guide: About 1 minute
1. Read to class: "You arrive at a land application site and observe the following situations."	
2. Show the slides depicting the problem. (Pooling of water and sinkholes)	Use Slide 179.2/13.2.2 Slide 179.2/13.2.2 is a photograph showing ponded wastewater on a spray irrigation site. It is obvious that the ponding is due to over application of wastewater and is not a deliberate area of ponding.
3. Ask the trainee groups to list the possible causes of the problem.	Use Slide 179.2/13.2.3 Slide 179.2/13.2.3 is a photograph showing a sinkhole with water in the bottom caused by land application of waste effluents.
B. Trainees analyze problem in work groups.	Guide: About 4 minutes
C. Problem Solution	Guide: About 5 minutes
1. Select one group to report findings.	
2. Encourage other groups to discuss the problem.	
3. Guide to problem solution:	
a. Identity of problem	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
The slides show farmed areas that contained pooled water areas and sinkholes.	
b. Possible Causes: 1) Broken pipe 2) Inoperative valve or other malfunction in the pipeline system. 3) Improper choice of site - poor soils for irrigation. 4) Irrigation at a rate beyond the capacity of the land area	
	Use Slide 179.2/13.2.4 Slide 179.2/13.2.4 is a blank.
III. Problem 2: Poor Corn Crop (10 minutes)	
A. Problem Statement	Guide: About 1 minute
1. Read to class: "At another site, the farmer who is farming the site for the town shows you an ear of corn from his farm (left hand) and from the spray irrigation area (right hand). He says he thinks that something's wrong."	
2. Show the slide depicting the problem.	Use Slide 179.2/13.2.5 Slide 179.2/13.2.5 is a photograph of the operator of a spray irrigation site holding two ears of corn. The ear on the left is smal and obviously undernourished. The ear on the right is large and healthy.
3. Ask the trainee groups to list the possible causes of the problem.	
B. Trainees analyze problem in work groups.	Guide: About 4 minutes

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
C. Problem Solution	Guide: About 5 minutes
1. Select one group to report findings.	
2. Encourage other groups to discuss the problem.	
3. Guide to problem solution:	
a. Identify of problem	
The slide shows a small corn ear, cobs not filled out with kernels, yellow corn leaves and the crop generally not responding.	
b. Possible causes:	
1) Too much water applied - over irrigation.	
2) Too little nutrients applied.	
3) Nutrients applied too early, perhaps wrong type of nutrient.	
	Use Slide 179.2/13.2.6 Slide 179.2/13.2.6 is a blank.
IV. Problem 3: Broken Pipe (10 minutes)	
A. Problem Statement	Guide: About 1 minute
1. Read to class:	
"Several of the installations you visit seen to be having problems with the piping used to transport wastewater effluents. You have seen examples like this."	
2. Show the slides depicting the problem.	Use Slide 179.2/13.2.7 Slide 179.2/13.2.7 is a photograph showing a section of corroded metal pipe used in a waste application site.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
	Use Slide 179.2/13.2.8 Slide 179.2/13.2.8 is a photograph showing a pressure rupture in a piece of aluminum irrigation piping.
	Use Slide 179.2/13.2.9 Slide 179.2/13.2.9 is a photograph showing a broken plastic spray irrigation line.
3. Ask the trainees to list the possible causes of the problem.	
B. Trainees analyze the problem in work groups.	Guide: About 4 minutes
C. Problem Solution	Guide: About 5 minutes
1. Select one group to report findings.	
2. Encourage other groups to discuss the problem.	
3. Guide to problem solution	
a. Identity of problem The slide shows deterioration of lateral distribution pipe.	
b. Possible causes:	
1) Effluent permitted to remain in aluminum pipe too long. Thus, nutrients in wastewater and dissimilar metals produced electrochemical corrosion. This would be expected between steel valves and spring and aluminum pipe.	
2) This happens also at grain boundaries along the pipe - after a certain amount of deterioration a pressure surge splits the pipe.	
3) Plastic pipe does not solve the problem of above ground surface lines, since during very cold weather, plastic pipes are easily	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
broken due to shockloads. In direct sunlight, plastic pipe deteriorates and then ruptures due to pressure surges. The high expansion also causes problems with riser locations and with leaks in very cold weather.	
	Use Slide 179.2/13.2.10 Slide 179.2/13.2.10 is a blank.
V. Problem 4: Erosion	
A. Problem Statement	Guide: About 1 minute
1. Read to class: "The operator of a wastewater renovation site indicates that his monitoring records show that overflow quality has deteriorated. You inspect the site and find what's shown on the slide." (Soil erosion by way of a large rut)	
2. Show slide depicting the problem.	Use Slide 179.2/13.2.11 Slide 179.2/13.2.11 is a photograph showing the operator's feet adjacent to a deep rut or erosion wash in the spray irrigation treatment area.
3. Ask the trainees to list the possible causes of the problem.	
B. Trainees analyze the problem in work groups.	Guide: About 4 minutes
C. Problem Solution	
1. Select one group to report findings.	
2. Encourage class discussion of the problem.	
3. Guide to problem solution	
a. Identity of problem The slide shows a rut caused by erosion of the farm area.	

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
b. Possible causes:	
1) Excessive application rate of wastewater	
2) Soil conditions not compatible with application rate.	
3) Crop cover not compatible.	
	Use Slide 179.2/13.2.12 Slide 179.2/13.2.12 is a blank.
VI. Lesson Summary (3 minutes)	
Note that the *Trainee Notebook* pages T13.2.1 - T13.2.8 contain troubleshooting guides on how to deal with the following common operational problems.	
A. Problems in Pumps and Pumping	Encourage class discussion.
1. Low pressure, high flow	
2. High pressure, low flow	
3. Low pressure, low flow	
B. Problems in Wastewater Distribution Systems	
1. Deterioration of lateral distribution pipe.	
2. No flow from certain sprinkler nozzles.	
3. Adequate management and operation of distribution systems.	
4. Spray from wind drift.	
C. Land Renovation Areas	
1. High overland runoff	
2. Soil erosion	
3. Dead crops	
4. Water pooling, sinkholes	
5. Poor crops	

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT SYSTEMS

Unit of Instruction 13: Land Treatment

Lesson 2: Troubleshooting Operational Problems

Trainee Notebook Contents

Troubleshooting Guide - Land Treatment T13.2.1
References T13.2.9

Troubleshooting Guide

Land Treatment

I. Wastewater Pumping

A. Problem: *Pressure for a particular setting is below normal; however the flow is above normal*

1. Possible Causes
    - a. Broken main, lateral, riser or gasket
    - b. Missing end plug, sprinkler, or nozzle tip
    - c. Too many laterals on at same time
2. Most Serious Effects
    - a. Low pressure, therefore poor distribution
    - b. Poor distribution, therefore poor renovation
    - c. Increased flow may cause increased horsepower and motor overload
    - d. High flow can cause pump cavitation
3. Corrections
    - a. Properly set automatic signaling device if pressure is below normal AND when exceptionally low, automatic pump cutoff
    - b. Normal maintenance and operation relative to the malfunctions listed.

B. Problem: *Flow for a particular setting is below normal; however, the pressure is above normal*

1. Possible Causes
    - a. Series of nozzle tips or sprinklers clogged
    - b. Lateral risers or valves clogged or partially clogged
    - c. Lateral screens may be clogged
    - d. Lateral valve may not have opened
    - e. Wastewater frozen anywhere in system
2. Most Serious Effects
    - a. High pressure can cause too much water in areas where sprinklers are operating
    - b. Too much water at any one location causes renovation problems

c. Too high pressure can cause wind drift and problems with the neighbors
d. Too high pressure can rupture lines, causing all types of problems - pollution, with neighbors, hydraulics, etc.

3. Corrections

a. Properly set automatically signaling device if pressure is above normal - AND when exceptionally high, automatic pump cutoff
b. Normal maintenance and operation relative to the malfunctions listed

C. Problem: *Both pressure and flow are below normal for all settings of the distribution system*

1. Possible Causes

a. Too much sand and grit in wastewater and impeller blades are worn
b. Too much wear in pump
c. Partially clogged suction or inlet screen

2. Most Serious Effects

a. Low pressure and poor distribution, renovation problems
b. Inability to pump enough water to keep up with inflow
c. Partially clogged screen on inlet to pump could cause cavitation and require financial outlay for entirely new pump

3. Corrections

a. Regular and detailed evaluation and troubleshooting by one having expertise in these areas
b. Use or properly installed and operating automatic pump cutoff for high partial vacuum on suction side of pump

II. Wastewater Distribution System

A. Problem: *Deterioration of lateral distribution pipe at ends or throughout pipe*

1. Possible Causes

a. Effluent permitted to remain in aluminum pipe too long. Thus, nutrients in wastewater and dissimilar metals produced electro-chemical corrosion. This would be expected between steel valves and springs and aluminum pipe.

b. This also happens at grain boundaries along the pipe - after a certain amount of deterioration, a pressure surge splits the pipe

c. Plastic pipe does not solve the problem of above ground surface lines, since during very cold weather plastic pipes are easily broken due to shockloads. In direct sunlight, plastic pipe deteriorates and then ruptures due to pressure surges. The high expansion-contraction coefficient of plastic also causes problems with riser locations and with leaks in very cold weather.

2. Most Serious Effects

   a. Pressure loss, therefore poor distribution
   b. Increased flow may cause increased horsepower and motor overload
   c. Wastewater runoff problems may occur

3. Corrections

   a. Bury lines of appropriate material
   b. Drain aluminum lateral lines except when actually in use
   c. Coat steel parts
   d. Cathotic or anodic protection

B. Problem: *No flow from certain sprinkler nozzles*

1. Possible Causes

   a. Particles in wastewater too large
   b. No suction line screen on pump or suction screen may have developed a hole, perhaps due to partial plugging of the screen. Thus, sprinkler nozzles may be clogged or riser may be clogged, or valve at end of lateral may be clogged, or screen at end of lateral may be clogged.

2. Most Serious Effects

   a. No wastewater applied where sprinklers clogged - poor crops
   b. Pressure too high where sprinklers open, thus too high flow causing crop damage and/or runoff
   c. High pressures can cause line damage

3. Corrections

   a. Adequate screening at the pumphouse
   b. Frequent and careful troubleshooting of system
   c. Proper maintenance and operation

C. Problem: *Adequate system management, particularly under adverse and severe weather conditions*

1. Possible Causes

    a. Adequate management and operation of field irrigation systems often require dedication above and beyond the regular call of duty, such as

        1) Changing valves in subfreezing weather
        2) Merely getting through the snow to where the valves are located
        3) Draining and flushing lines regularly, especially in winter

    b. Many standard O & M procedures are neglected during freezing temperatures, rain storms or excessive snow days
    c. Working in wet grass up to one's waist isn't fun

2. Most Serious Effects

    a. Sprinklers clog, "lines" freeze and break
    b. Poor distribution, excess runoff
    c. All problems in all sections listed in this guide occur
    d. Wet ice is extremely slippery, expecially on slopes, safety must be considered

3. Corrections

    a. Adequate salary for employees
    b. Adequate inspection with knowledgeable tips and assistance
    c. Probably most of all, however, is appropriate praise and respect for a job well done, i.e., good management practices are needed to get the most out of the people who must maintain and operate a land treatment system

D. Problem: *Wind drifting spray onto neighbors' property*

1. Possible Causes

    a. May not have been considered in design
    b. Equipment designed to stop pumps when wind comes from specific direction or reaches specific speed may have malfunctioned
    c. Wind break planted for this purpose may not have grown to adequate height as yet
    d. Sprinklers may be operating at a higher pressure than that for which they were designed
    e. Traveling sprinkler may be permitted to move too close to the field border
    f. Original wind break may have been removed

2. Most Serious Effects

   a. This could vary anywhere from farmer being happy to receive this water and nutrients to
   b. The municipality being brought into a lawsuit by a neighbor who thinks he/she has more infections and problems than usual

3. Corrections

   a. Provide a larger buffer area in relation to neighboring properties
   b. Adjust or move distribution system to make sure spray remains within renovation area

III. Land Renovation Areas

A. Problem: *Water is flowing off application area with or without erosion*

1. Possible Causes

   a. Related to renovation system
      1) Infiltration rate too low - poor soils
      2) Soil surface sealed by solids preventing infiltration
      3) Waste material forms mass on soil surface which destroys soil aggregation and prevents infiltration
   b. Related to distribution system
      1) Irrigation rate too high
      2) Broken line or deteriorated pipe
      3) Broken coupler latch or displaced end plug
      4) Nozzles broken at other locations, thereby increasing pressure and flow at one application point
   c. Too much rain in recent past

2. Most Serious Effects

   a. Wastewater runs off area without being renovated
   b. Pollution of neighboring property, water supplies, etc.

3. Corrections

   a. Related to renovation system
      1) Strip crop area or put into permanent sod
      2) Terrace or use diversions
      3) Underdrain if soil is appropriate, etc.
      4) Keep soil well covered with grass or mulch
      5) Irrigate only sandy single grained soils
      6) Keep BOD low enough to be compatible with temperature, soil, crop, etc.

b. Related to distribution system
    1) Condition can be corrected primarily by normal operation and maintenance
    2) Place sprinklers farther apart
    3) Decrease nozzle diameter of each sprinkler and increase the length of laterals and number of sprinklers
    4) Reduce irrigation rate

c. Don't irrigate if soil is saturated from natural rainfall

B. Problem: *Erosion of soil*

1. Possible Causes

    a. Most of the causes of Problem A can also cause soil erosion
    b. Land remaining uncovered over long periods
    c. Planting of the wrong crop for the soil

2. Most Serious Effects

    a. Loss of fertile soil
    b. Poor quality runoff, downstream water quality problems, including nutrients and pesticides
    c. Deposition of soil in ditches, canals and downstream waterways

3. Corrections

    a. Most of the corrections for Problem A may be applicable
    b. If problem is with crop or soil, consult county agent or other agricultural specialist

C. Problem: *Crop that was being irrigated is dead*

1. Possible Causes

    a. Too much water applied
    b. Too much of a certain nutrient applied, i.e., crops need certain nutrients and only certain amounts of these. Too much of most any nutrient will kill the crop
    c. Too much of any type detrimental chemical - weed killers, etc. through treatment plant - from area runoff or disposed of through drains

2. Most Serious Effect

   a. "Dead crop makes a darn poor living filter," i.e., the system just isn't working
   b. Dead crop adds to BOD load
   c. Infiltration is decreased, runoff can occur or increase
   d. Nutrients are not removed
   e. Unsightly area - neighbors are concerned
   f. Excess odors - neighbors are concerned

3. Corrections

   a. Close monitoring of all inflows to the treatment plant including industrial wastes
   b. Monitor plant effluent for toxic materials
   c. Reduction of high flow rates
   d. Modification of nutrient balance applied to the crop
   e. Consult with county agent or other agricultural specialist

D. Problem: *Areas of water pooling or sink holes*

1. Possible Causes

   a. Broken mainline
   b. Inoperative valve, mechanical or electrical malfunction
   c. Electrochemical corrosion
   d. Insufficient pressure to seal portable pipe
   e. Improper choice of site in design or adding water beyond design limits
   f. Any malfunction or imporper operation that causes an excess of wastewater to be discharged

2. Most Serious Effects

   a. Dangerous to farm operating equipment
   b. Unsafe to man and animals, especially before final cover on surface has fallen in
   c. Pollution of groundwater in general or private, town or industrial water source which usually ends in law suit
   d. Continued loss of renovation effect, possible loss of use of entire system, which is tremendous financial loss

3. Corrections

   a. Inspection and evaluation by professional persons with expertise and experience in this area
   b. Install adequate surface drainage early in construction or very early in operation
   c. Sound maintenance operation with lots of good common sense

E. Problem: *Small corn ears, cobs not filled out with kernels, yellow corn leaves, crop not responding as it ought*

1. Possible Causes

   a. Too much water applied, same as before
   b. Too little nutrients applied
      1) Crop does not have enough nutrients to go to maturity
      2) Crop too thick for nutrients applied
      3) Too much grass in corn, competition
   c. Nutrient applied too early
      1) Then irrigation water leached nutrients through soil into groundwater or out to stream (this nutrient loading may be worse than original effluent)
   d. Nutrients may have been of wrong type for time they were applied

2. Most Serious Effects

   a. Poor economical balance
   b. Increased pollution per nutrient leaching
   c. Detrimental outlook effect on farmer, operator, etc., thus have "don't care" attitude in other work

3. Corrections

   a. Advice from county agent, S.C.S. and/or other professional agricultural consultants with this type of experience
   b. Good operation and maintenance of entire distribution and renovation system

REFERENCES

1. Butler, Robert M. et al, *Spray Irrigation Disposal of Wastewater*, Sp. Circ. 185, Ag. Ext. Euc., The Pennsylvania State University, University Park, PA (1974).

2. *Costs of Wastewater Treatment by Land Application*, Office of Water Program Operations, U. S. Environmental Protection Agency, Washington, D.C. (June, 1975).

3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, Municipal Operations Branch, U. S. Environmental Protection Agency, Washington, D.C.

4. Kardos, L. T., et al, *Renovation of Secondary Effluent for Reuse as a Water Resource*, EPA 660/2-74-016, U. S. Environmental Protection Agency, Office of Research, Cincinnati, Ohio (February, 1974).

5. *Land Application of Sewage Effluents and Sludges: Selected Abstracts*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (June, 1974).

6. Malhotra, Sudarshan K. and Myers, Earl A., "Design, Operation and Monitoring of Municipal Land Irrigation Systems in Michigan, WPCF Conference, Denver, Colorado (October, 1974).

7. Metcalf and Eddy, Inc., *Wastewater Engineering Treatment Disposal Reuse*, pages 760-824, McGraw-Hill Book Company, New York (1979).

8. Myers, Earl A., "Management of Land Disposal Systems for Adequate Renovation," AIChE Conference Proceedings, Chicago, Illinois (May, 1975).

9. Myers, Earl A. and Burt, Edward A., "Automation of Wastewater Land Application Systems," Sprinkler Irrigation Association Conference Proceedings, Atlanta, Georgia (February, 1975).

10. *Operation of Wastewater Treatment Plants MOP 11*, pages 359-380, Water Pollution Control Federation, Washington, D.C. (1973).

11. Pound, C. E. and Crites, R. W., *Wastewater Treatment and Reuse by Land Application*, Volumes I and II, U. S. Environmental Protection Agency, Washington, D.C. (August, 1973).

12. *Process Design Manual Municipal Sludge Landfills*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (October, 1978).

13. *Process Design Manual Sludge Treatment and Disposal*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio, (September, 1979).

14. "Recycling Municipal Sludges and Effluents on Land," National Association of State Universities and Land-Grant Colleges, July, 1973.

15. *Sludge Treatment and Disposal. Process Design Manual*, Technology Transfer, U. S. Environmental Protection Agency, Cincinnati, Ohio (October, 1974).

16. Sopper, W. E. and Kardos, L. T., editors, *Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland*, in Symposium Proceedings at University Park, PA, The Pennsylvania State University Press, August, 1973, 479 pages.

17. Sullivan, R. H., Cohn, M. M. and Baxter, S. S., *Survey of Facilities Using Land Application of Wastewater*, American Public Works Association, U. S. Environmental Protection Agency, Washington, D.C. (July, 1974).

1436

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 14: Disinfection

Unit 14 of 15 Units of Instruction

Lessons in Unit: 2 Recommended Time: 60 minutes

Instructor Overview of the Unit

Rationale for the Unit: Many plants encounter problems in meeting discharge requirements of 200 fecal coliforms per 100 milliliters or properly controlling disinfectant dosage to avoid effluent toxicity problems. This unit introduces the topics of chlorination and ozonation to familiarize the troubleshooter with common problems encountered with effluent disinfection systems.

Trainee Entry Level Behavior: The trainee should have completed Units of Instruction 1: *Overview* and 2: *Elements of Troubleshooting* before beginning this Unit.

Trainee Learning Objectives: At the conclusion of this Unit of Instruction, the trainee will be able to:

1. List and describe the principal components and characteristics of chlorination and ozonation type disinfection systems.
2. Identify both the controllable and uncontrollable factors in the operation of chlorination and ozonation type disinfection systems.
3. List and identify the most common problems in operating disinfection systems.
4. Recognize and explain problem indicators and visual observations necessary for troubleshooting disinfection systems.
5. List and explain tests and analyses for troubleshooting disinfection systems.
6. List methods of correction for common problems in operating disinfection systems.

Sequencing and Pre-Course Preparation for Unit: Unit 14, *Disinfection,* is presented as two lessons.

Lesson 1: Chlorination

Recommended Time: 30 minutes

Purpose: Discuss the purposes and use of chlorine in wastewater treatment and identify common problems encountered in chlorination systems.

Training Facilities:

a. Large room, preferably 40' x 40', set in "herring bone" or "U" shape, with table and chair seating for 32 trainees.

b. Instructor table with lectern.

c. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.

d. Easel with pad.

e. 35mm carousel projector with remote control changer at instructor table.

f. At least four empty carousel trays.

g. Overhead projector.

h. Chalk. felt-tip marker, erasers, etc.

i. Six to eight chairs randomly spaced at back and sides of room for visitors.

Pre-Course Preparation: No specific pre-course preparation is required for this lesson.

Instructional Approach: Illustrated lecture

Lesson 2: Ozonation

Recommended Time: 30 minutes

Purpose: Discuss the purposes and use of ozone in wastewater treatment and identify common problems in ozonation systems.

Training Facilities: As specified for Lesson 1.

Pre-Course Preparation: No specific pre-course preparation is required for this lesson.

Instructional Approach: Illustrated lecture.

Presentation Options for the Course Director: This Unit is designed to provide only a brief introduction to wastewater disinfection systems. The Course Director may wish to expand this lesson significantly depending on the needs of the class.

Summary of Unit of Instruction 14: Disinfection

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Chlorination 30 minutes	1. Define purposes of chlorination in wastewater treatment	1. Purposes of chlorination	1. Illustrated lecture	1. *Instructor Notebook*, pages 14.1.1-14.1.14
	2. Identifying types of chlorination systems	2. Types of chlorination systems	2. Frequent trainee reference to *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*	2. Slides 179.2/14.1.1-179.2/14.1.18
	3. Identify common problems in chlorination system operations	3. Common operational problems		3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pp. 129-141
2. Ozonation	1. Define purposes of ozonation	1. Purposes of ozonation	1. Illustrated lecture	1. *Instructor Notebook*, pages 14.2.1-14.2.8
	2. Describe ozonation system	2. Ozonation system	2. Frequent trainee reference to *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*	2. Slides 179.2/14.2.1-179.2/14.2.8
	3. Identify common problems in ozonation system operations	3. Common problems in ozonation		3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*
				4. *Trainee Notebook*, page T14.2.1

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 14: Disinfection

Lesson 1: Chlorination

Lesson 1 of 2 lessons Recommended Time: 30 minutes

Purpose: This lesson discusses the purposes and uses of chlorination in wastewater treatment, describes chlorine feed systems and identifies common operational problems in chlorination systems.

Trainee Entry Level Behavior: The trainee should have achieved the learning objectives specified for Unit of Instruction 2, *Elements of Troubleshooting*, before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to:

1. List the properties of chlorine.
2. List emergency and safety equipment which should be available when chlorine is being used.
3. List the uses of chlorination in wastewater treatment.
4. Describe liquid and gaseous chlorination systems.
5. Using references, list common problems encountered in wastewater chlorination operation.

Instructional Approach: Illustrated lecture.

Lesson Schedule: The 30 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 10 minutes	Introduction and Properties of Chlorine
10 - 20 minutes	Chlorination Systems
20 - 30 minutes	Operational Problems

Trainee Materials Used in Lesson: Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities, pp. 129-141.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 14, Lesson 1, pages 14.1.1 - 14.1.14.
2. Slides 179.2/14.1.1 - 179.2/14.1.18.

Instructor Materials Recommended for Development: Photographs of chlorination equipment may be added to the lesson materials.

Additional Instructor References:

1. White, G. C., *Handbook of Chlorination*, Van Nostrand Reinhold Company, New York (1972).
2. "WPCF Wastewater Treatment Skill Training Package Chlorination," Water Pollution Control Federation, Washington, D.C. (1979).
3. *Chlorine Institute Manual*, Bulletin 70-9001, The Chlorine Institute, New York.
4. Layton, R. F., "Disinfection of Wastewaters," *Journal of the Missouri Water and Sewage Conference* (1975).
5. Ministry of the Environment-Ontario, "Basic Gas Chlorination Workshop Manual," Toronto, Ontario, Canada (June, 1977)
6. U. S. Environmental Protection Agency, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA-430/9-78-001 (January, 1978).
7. Water Pollution Control Federation, *Chlorination of Wastewater, Manual of Practice 4*, Washington, D.C. (1976).
8. Water Pollution Control Federation, *Wastewater Treatment Plant Design, Manual of Practice 8*, Washington, D.C. (1977)
9. Water Pollution Control Federation, *Operation of Wastewater Treatment Plants, Manual of Practice 11*, Washington, D.C. (1976).

Classroom Set-Up:

1. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees.
2. Instructor table with lectern.
3. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.

4. Easel with pad.

5. 35mm carousel projector with remote control changer at instructor table.

6. At least four empty carousel trays.

7. Overhead projector.

8. Chalk, felt-tip marker, erasers, etc.

9. Six to eight chairs randomly spaced at back and sides of room for visitors.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
I. Introduction and Properties of Chlorine (10 minutes)	Use Slide 179.2/14.1.1 Slide 179.2/14.1.1 is a blank.
A. Uses of Chlorine in Wastewater Treatment	
1. Disinfection	Note: Will limit discussion to disinfection use.
2. Odor Control	
3. Activated Sludge Bulking Control	
4. Filter Fly Control in Trickling Filters	
5. Nitrogen Removal (Breakpoint chlorination)	
B. Types of Chlorine Commonly Used	
1. Liquid/Gas Chlorine	
a. 100 lb cylinder	Note: Discussion will be limited to 150 lb cylinder and hypochlorite systems.
b. 150 lb cylinder	
c. 2000 lb cylinder	
d. Tank car	
2. "Solid" Chlorine	
a. Hypochlorite	
1) Sodium	
2) Calcium	
b. Fed as a solution	
3. Chlorine Dioxide	
C. Disinfection	Use Slide 179.2/14.1.2 Slide 179.2/14.1.2 is a word slide which reads:
1. Define disinfection using Slide 179.2/14.1.2 and contrast disinfection to sterilization.	"Disinfection
2. Efficiency dependent on many variables	Purpose: To remove (kill) pathogenic organisms to a specified safe level
a. Chlorine Residual	

LESSON OUTLINE

b. Contact Time

c. Temperature

d. pH

e. Mixing efficiency

f. Contacting pattern

g. Turbidity (suspended solids)

3. Control

   a. Residual Chlorine Concentration after specified contact time (usually 0.5 mg/l combined residual after 30 minutes contact).

   b. Fecal Coliform Count as indicator organism for pathogens (200 F.C./ 100 ml geometric mean)

4. Requirements for Good Disinfection

   a. Continuous application

   b. Rapid mixing at point of application

   c. Adequate contact time (plug flow conditions)

   d. Efficiency decreases with decreasing temperature

   e. Efficiency increases with increasing concentration of disinfectant

   f. Chlorine disinfection most efficient with pH near neutral (pH = 7) or with slightly acidic conditions (6 < pH < 7)

KEY POINTS & INSTRUCTOR GUIDES

Efficiency: Dependent on residual levels and contact time

Control: Combined Chlorine Residual
Fecal Coliform

General Requirements (varies):
Not to exceed 0.5 mg/l
200 F.C./100 ml geometric mean"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
D. Properties of Chlorine	
1. Use Slide 179.2/14.1.3 to briefly review properties of gaseous chlorine.	Use Slide 179.2/14.1.3 Slide 179.2/14.1.3 is a word slide which reads: "Properties of Chlorine · Greenish Yellow Gas · 2 1/2 Times Heavier than Air · Slightly Soluble in Water · Pungent and Irritating Odor · Pressure Change with Temperature"
2. Use Slide 179.2/14.1.4 to briefly review chemical properties of chlorine. a. Chlorine is non-flammable but supports combustion because it is a strong oxidizing agent. b. Must not expose flammable substances to chlorine or hypochlorite	Use Slide 179.2/14.1.4 Slide 179.2/14.1.4 is a word slide which reads: "Behavior of Chlorine · Non-Flammable · Non-Explosive · Non-Conductive Electrically · Corrosive in the Presence of Moisture · Highly Reactive · Oxidizing Agent"
3. Use Slide 179.2/14.1.5 to briefly review health hazards with chlorine.	Use Slide 179.2/14.1.5 Slide 179.2/14.1.5 is a word slide which reads: "Health Hazards of Chlorine · Excessive Amount is Fatal · Not Cummulative · Irritating to Eyes and Skin · Respiratory System is Vulnerable"
4. Use Slide 179.2/14.1.6 to briefly review emergency equipment which should be available.	Use Slide 179.2/14.1.6 Slide 179.2/14.1.6 is a word slide which reads: "Emergency Equipment to Have · Gas Mask Outside Chlorine Room · Emergency Kit · Alkali or Alkali Solution · Ammonia Water · Air Pack · Goggles and Boots"

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
5. Use Slide 179.2/14.1.7 to briefly review chlorine first aid.	Use Slide 179.2/14.1.7 Slide 179.2/14.1.7 is a word slide which reads: "First Aid for Chlorine Exposure · Flush Eyes and Skin with Warm Water · Artificial Respiration if Necessary · Move Patient Outside · Keep Warm · Call Physician"
II. Chlorination Systems (10 minutes) A. 150 lb Cylinder Gas Chlorination	
1. Use Slide 179.2/14.1.8 to illustrate components of a 150 lb chlorine system. a. Cylinder b. Fusible plug c. Valve seat d. Packing e. Packing nut f. Stem g. Outlet cap h. Lead washer	Use Slide 179.2/14.1.8 Slide 179.2/14.1.8 is a schematic diagram of the valve components for 150 lb chlorine cylinder
2. Cylinder contains liquid chlorine which evaporates and is fed as a gas. a. Heat for evaporation is by ambient transfer through cylinder. b. Maximum feed rate is about 18 kg (40 lbs) per day at normal temperature (about 68°C).	

LESSON OUTLINE

c. Excessive withdrawal from cylinder causes the temperature to drop and pressure in the cylinder to drop.

d. Inadequate chlorine feed or inadequate pressure may be caused by using too few cylinders to supply chlorine. Add cylinders to service manifold if this is the problem.

3. Use Slide 179.2/14.1.9 to illustrate a properly manifolded 150 lb chlorine cylinder.

   a. Components

      1) Yoke clamp
      2) Adapter
      3) Auxiliary valve
      4) Flexible connection
      5) Manifold valve
      6) Manifold

   b. Check system for proper materials and leaks (ammonia water bottle).

   c. Adequate pressure in the cylinder but no chlorine feed may be caused by blockage in the manifold or the manifold connection.

4. Use Slide 179.2/14.1.10 to illustrate the parts of a gas chlorinator.

   a. Components

      1) Pressure regulating valve
      2) Pressure relief valve
      3) Flow meter
      4) Flow rate valve
      5) Vacuum regulating valve
      6) Injector

   b. Potential problem indicators

      1) Inability to maintain required chlorine residual may be caused by:

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/14.1.9
Slide 179.2/14.1.9 is a schematic diagram showing the proper connection of a chlorine cylinder to the feed manifold.

Use Slide 179.2/14.1.10
Slide 179.2/14.1.10 is a schematic diagram of a gas chlorinator.

Refer class to pp. 137-141 in *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities.*

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDES

- a) Changes in wastewater flow rates
- b) Changes in wastewater effluent characteristics
- c) Malfunction of the chlorinator

2) Indicators of chlorinator problem
    - a) Cannot obtain maximum rated feed rate
    - b) Cannot obtain low feed rate
    - c) Erratic flow meter float position
    - d) Feed rate meter readings don't tally with daily chlorine usage

3) Troubleshooting the chlorinator
    - a) Check Injector Vacuum which should be at least 127 mm (243 mm for variable vacuum chlorinator)
        1. Check and clean injector throat and tailway.
        2. Clean or replace solution tubing
        3. Provide adequate water pressure
    - b) Check vacuum differential across flow rate valve and vacuum regulating valve which should be 21-32 mm Hg.
        1. Check injector for adequate vacuum as in a) above if vacuum differential is not in the proper range and chlorinator will not feed at maximum rate.

LESSON OUTLINE

2. If cannot control in low feed range, may need to replace the vacuum regulating valve or the diaphragm.

c) Check Pressure Regulating Valve (PRV) by reading vacuum at inlet to the flow meter. Expected readings are:

Chlorinator Capacity	Vacuum Readings
400 lb	43 - 60 mm Hg
2,000 lb	21 - 32 mm Hg
8,000 lb	21 - 32 mm Hg

(Subtract 15 mm for variable vacuum chlorinator)

Readings out of range may indicate:

1. Dirt in PRV seat which prevents it from shutting.
2. Vacuum leak - probably in vacuum relief valve or its piping.
3. Partially or completely clogged PRV or gas line.
4. Leak between flow rate valve and the vacuum regulating valve.

B. Ton Cylinder

1. Use Slide 179.2/14.1.11 to illustrate feed valving in ton cylinder.
   - a. Draw liquid chlorine
   - b. Draw gaseous chlorine
   - c. Maximum feed rate of gas from ton cylinder is about 400 lb/day.

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/14.1.11

Slide 179.2/14.1.11 is a schematic diagram showing feed valving for ton cylinders.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
2. Use Slide 179.2/14.1.12 to illustrate components in a liquid chlorine feed system. a. Chlorine cylinder b. Rupture disk c. Expansion chamber d. Evaporator e. Filter f. Pressure Reducing Valve	Use Slide 179.2/14.1.12 Slide 179.2/14.1.12 is a schematic diagram of a liquid feed chlorine system showing the components listed on the left.
3. Use Slide 179.2/14.1.12 to illustrate the components of a chlorine evaporator. a. Liquid supply line b. Control panel c. Heater d. Water system e. Chlorine gas outlet	Use Slide 179.2/14.1.13 Slide 179.2/14.1.13 is a schematic diagram of a chlorine evaporator.
C. Hypochlorination 1. Hypochlorites used a. Sodium hypochlorite b. Calcium Hypochlorite	
2. Hypochlorite feed system a. Chemical solution system b. Liquid level switch c. Mixer d. Metering pump e. Discharge line f. Chlorine application point	Use Slide 179.2/14.1.14 Slide 179.2/14.1.14 is a schematic diagram of a hypochlorination system.

LESSON OUTLINE

3. Hypochlorite Metering Pump
    a. Pumphead
    b. Diaphragm
    c. Suction valve
    d. Discharge valve
    e. Feed rate control
    f. Electric motor
    g. Pump housing

D. Chlorine Contact Chamber

1. Use Slide 179.2/14.1.16 to describe typical chlorine contact chamber.
    a. Usually designed for plug flow and 15-30 minutes contact time at peak flow.
    b. Length:width should be about 40:1 to give good plug flow characteristics
    c. Most common problems are:
        1) Inadequate contact time
        2) Short-circuiting
        3) Inadequate mixing of chlorine solution and wastewater
    d. Have class discuss possible solutions to above problems.
        1) Improve baffling
        2) Mechanical mixing

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/14.1.15
Slide 179.2/14.1.15 is a schematic diagram of a hypochlorite metering pump.

Use Slide 179.2/14.1.16
Slide 179.2/14.1.16 is a schematic diagram showing an over and under baffle system chlorine contact chamber plan view

Use Slide 179.2/14.1.17
Slide 179.2/14.1.17 is a word slide which reads:

"Upgrading Chlorine Contact Tanks

- Improve Detention
- Improve Mixing Characteristics
- Eliminate Short Circuiting
- Improve Chlorine Diffuser System
- Lengthen Contact Time"

LESSON OUTLINE

KEY POINTS &
INSTRUCTOR GUIDES

E. Residual Chlorine Control Systems

1. Manual

   a. Grab sample to analyze for residual chlorine

   b. Manually adjust chlorine dosage

2. Open Loop Flow Proportioned

   a. Chlorine feed rate is proportioned to inlet flow rate

   b. Manually adjust dosage (lbs/MG) to respond to changes in effluent characteristics

3. Closed Loop Residual Control

   a. Usually flow proportioned

   b. Automatically sample

   c. Automatic amperometric chlorine residual analyzer

   d. Residual analyzer generates control signal to adjust chlorine dosage

   e. Major problems are:

      1) Mechanical - keeping the system running properly

      2) Excessive loop "dead time" (dead time greater than 5 minutes) can result in erratic control response. Solve by relocating chlorine addition point (injector adjacent to application point) and residual sample point 15-30 seconds flow time downstream from application point.

LESSON OUTLINE

III. Common Problems in Chlorination (10 minutes)

A. Poor Contact Tank Design

1. Eliminate short circuiting
2. Improve mixing
3. Improve Chlorine diffuser system
4. Lengthen contact time

B. Excessive and Erratic Chlorine Use

1. Partial nitrification in biological system produces NO_2^- which has high Cl_2 demand.
2. Improper automatic controls

C. High Fecal Coliform in Effluent

1. High effluent TSS interfers with disinfection.
2. Poor contact tank design
3. Inadequate chlorine dosages
4. High effluent pH causes poor disinfection efficiency
5. Low wastewater temperature

D. Refer Class to pages 137-141 in *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* and review other chlorination problems.

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/14.1.18
Slide 179.2/14.1.18 is a blank.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT PROBLEMS

Unit of Instruction 14: Disinfection

Lesson 2: Ozonation

Lesson 2 of 2 lessons Recommended Time: 30 minutes

Purpose: Ozonation is becoming increasingly popular for odor control and disinfection in wastewater treatment facilities. This lesson provides a review of ozonation and introduces some of the operational problems encountered in ozonation.

Trainee Entry Level Behavior: The trainee should have achieved the learning objectives specified for Unit of Instruction 2, *Elements of Troubleshooting*, before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson the trainee should be able to:

1. Describe the chemistry of ozone disinfection.
2. Describe three processes for on-site generation of ozone.
3. Identify common operational problems with ozonation systems.

Instructional Approach: Illustrated lecture.

Lesson Schedule: The 30 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 10 minutes	Ozone Chemistry
10 - 20 minutes	Ozonation Systems
20 - 30 minutes	Operational Problems

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, page T14.2.1, "References."
2. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, pp. 142-151.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 14, Lesson 2, pages 14.2.1 - 14.2.8.
2. Slides 179.2/4.2.1 - 179.2/14.2.8.

Instructor Materials Recommended for Development: The instructor may supplement the lesson with photographs of ozone disinfection installations.

Additional Instructor References: See Unit 14, Lesson 1, page 14.1.2.

Classroom Set-Up: As specified for Unit 14, Lesson 1.

LESSON OUTLINE

I. Ozone Chemistry (10 minutes)

- A. Define Ozone as O_3
  1. Allotropic form of oxygen
  2. Unstable blue gas
  3. Pungent odor
  4. Strong oxidizing agent
  5. Slightly soluble in water
- B. Produced in Presence of High Voltage Electrical Discharge (4000-30,000 volts)
- C. In aqueous solution ozone dissociates to liberate a nacent oxygen atom which is very reactive. Ultimate product of dissociation is oxygen (O_2).
  1. Nacent oxygen (O) is very active oxidizing agent.
  2. Reactivity results in very effective disinfectant.
- D. Advantages of Ozonation for Disinfection
  1. High germicidal effectiveness even against resistant organisms such as viruses and cysts.
  2. Dissolved oxygen as a residual product thus no residual toxicity.
  3. No dissolved solids added.
  4. Disinfecting power not affected by pH or ammonia content.

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/14.2.1
Slide 179.2/14.2.1 is a blank.

Use Slide 179.2/14.2.2
Slide 179.2/14.2.2 is a word slide which reads:

"Ozone - O_3

In High Voltage Electrical Discharge

$$O_2 \rightleftarrows O + O$$

$$O + 2O_2 \rightleftarrows O_3 + O_2$$

In Aqueous Solution

$$O_3 \rightleftarrows O_2 + O$$

$$O + O_3 \rightleftarrows 2O_2$$

LESSON OUTLINE

E. Disadvantages of Ozonation for Disinfection

1. More costly than chlorine because of high electrical costs to produce.

2. High organic content in the wastewater competes for available ozone (high TSS interfers with disinfection).

3. No long term residual disinfection capability.

II. Ozonation Systems (10 minutes)

A. System Components

1. Air Supply System

a. Air supply must be cold, clean and dry. Therefore need:

1) Air blower
2) Air filter
3) Air cooler
4) Air dryer

b. Modern plants design for 0.03 ppm moisture in air supply.

c. In one plant ozone production was reduced from 225 gm/hr to 160 gm/hr when moisture was increased from 2.3 to 4.6 ppm.

2. Ozone Generator

a. Types

1) Refer class to page 146, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*.

2) Types

a) Plate
b) Tube
c) Lowtherm plate

KEY POINTS & INSTRUCTOR GUIDES

Use Slide 179.2/14.2.3
Slide 179.2/14.2.3 is a word slide which reads:

"Ozone System Components

- Air Blower
- Air Filter
- Air Cooler
- Air Dryer
- Ozone Generator
- Ozone Injector
- Ozone-Water Contact Basin
- Ozone Destruction System"

b. Operation

1) Clean, cool, dry air supply at about 1 atm pressure

2) Electrical power

a) 4,000-30,000 volts

b) 500 - 1,000 Hz

3) Follow manufacturers recommendations for O & M

4) Refer class to page 148, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* for typical design and operating data.

3. Ozonator

a. Ozone injector

b. Ozone contact basin

c. Good mixing because of low solubility of ozone in water.

d. At least 5 minutes contact time for disinfection.

4. Need ozone destruction system to decompose excess ozone which excapes the contact system because of high ozone toxicity.

B. Typical Ozone Systems

1. Refer class to page 143, *Field Manual for Performance Evaluation and Troubleshooting At Municipal Wastewater Treatment Facilities* for flow diagrams.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
2. Illustrate typical process flows	
a. Once-through Air Process	Use Slide 179.2/14.2.4 Slide 179.2/14.2.4 is a schematic diagram of the once-through air process.
b. Oxygen Recycle Process	Use Slide 179.2/14.2.5 Slide 179.2/14.2.5 is a schematic diagram of the Oxygen Recycle system.
c. Once-through Oxygen Process	Use Slide 179.2/14.2.6 Slide 179.2/14.2.6 is a schematic diagram of the once-through oxygen process.
d. Ozone Contact Basin	Use Slide 179.2/14.2.7 Slide 179.2/14.2.7 is a schematic diagram of a typical ozone contact basin with porous diffusers.
	Use Slide 179.2/14.2.8 Slide 179.2/14.2.8 is a blank.
III. Operational Problems (10 minutes)	Instructor should emphasize the troubleshooter's role in assisting the operator to establish and maintain the ozonation system in accordance with the manufacturer's recommendations. Many of the problems are mechanical or electrical in nature. If the operator is having frequent recurrence of any of the problems listed, the troubleshooter should work with the operator and the manufacturer's representative to identify the cause of the problem and to affect a permanent solution.
A. Refer class to pages 150-151, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities* for troubleshooting guides on ozonation systems.	

LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDES

B. Using the following guide, lead class discussion of the common problems with ozonation systems with emphasis on the troubleshooter's role as an advisor to the operator.

1. Problem: Ozone generator overheats and shuts down

   Solution: Clean louvers
   Lubricate fan bearings or remove obstructions hampering rotation
   Tighten or replace belts

2. Problem: No voltage or current to the generator

   Solution: SCR fuse blown
   a. Replace SCR fuse
   b. Replace surge arrestor
   c. Replace SCR's

   Control circuit blown
   a. Find and repair fault
   b. Replace control fuses

   Interlock circuit failure

   a. Replace panel or door interlock switches
   b. Check reset mechanisms, establish proper gas flow

   No main power - reset main breaker

3. Problem: Full voltage, no current

   Solution: Fuses, locate fault and repair
   Relays and heaters, reset relays

4. Problem: Low ozone production

   Solution: Find leak in feed gas system and repair
   Check fuses

Clean cell modules in accordance with manufacturer's instructions; insure cooling air is clean

Establish proper feed pressure

5. Problem: Ozone leak

   Solution: Tighten or repair connection

6. Problem: Inadequate disinfection

   Solution: Increase dosage

   Improve plant performance upstream

   Clean diffuser or replace

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 14: Disinfection

Lesson 2: Ozonation

Table of Contents

References T14.2.1

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

REFERENCES

1. *Chlorine Institute Manual*, Bulletin 70-9001, The Chlorine Institute, New York.

2. Layton, R.F., "Disinfection of Wastewaters," *Journal of the Missouri Water and Sewage Conference* (1975).

3. Ministry of the Environment - Ontario, "Basic Gas Chlorination Workshop Manual," Toronto, Ontario, Canada (June, 1977).

4. U. S. Environmental Protection Agency, *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities*, EPA-430/9-78-001 (January, 1978).

5. "WPCF Wastewater Treatment Skill Training Package Chlorination", Water Pollution Control Federation, Washington, D.C. (1979).

6. Water Pollution Control Federation, *Chlorination of Wastewater, Manual of Practice 4*, Washington, D.C. (1976).

7. Water Pollution Control Federation, *Operation of Wastewater Treatment Plants, Manual of Practice 11*, Washington, D.C. (1976).

8. Water Pollution Control Federation, *Wastewater Treatment Plant Design, Manual of Practice 8*, Washington, D.C. (1977).

9. White, G. C., *Handbook of Chlorination*, Van Nostrand Reinhold Company, New York (1972).

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 15: Closing

Unit 15 of 15 Units of Instruction

Lessons in Unit: 2 Recommended Time: 60 minutes

Instructor Overview of the Unit

Rationale for Unit: The *Closing* unit provides a brief summary of the materials presented in the course. A post-test to measure trainee achievement is administered. Certificates of completion are awarded.

Trainee Entry Level Behavior: The trainees should have successfully completed all units of instruction included in the course agenda before beginning the *Closing* Unit.

Trainee Learning Objectives: At the conclusion of this Unit of Instruction, the trainee will be able to:

1. From memory, describe the process of troubleshooting and explain how the process of troubleshooting is applied to problem solving in wastewater treatment facilities.
2. Demonstrate his/her achievement of the trainee learning objectives for the course by successfully completing the post-test.

Sequencing and Pre-Course Preparation for the Unit: Unit 15, *Closing* is presented as two lessons.

Lesson 1. Course Summary

Recommended Time: 30 minutes

Purpose: Summarize the process of troubleshooting and discuss the application of the process of troubleshooting to problem solving in wastewater treatment facilities.

Training Facilities:

a. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees

b. Instructor table with lectern.

c. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.

d. Easel with pad.

e. 35mm carousel projector with remote control changer at instructor table.

f. At least four empty carousel trays.

g. Overhead projector.

h. Chalk, felt-tip markers, erasers, etc.

i. Six to eight chairs randonly spaced at back and sides of room for visitors.

Pre-Course Preparation: No specific pre-course preparation is required for Unit 15, Lesson 1.

Instructional Approach: Illustrated lecture.

Lesson 2. Trainee Post-Course Assessment

Recommended Time: 30 minutes

Purpose: Document trainee achievement of course objectives using a written post-test.

Training Facilities: As specified for Unit 15, Lesson 1

Pre-Course Preparation:

1. Structure the post-course assessment examination by selecting appropriate questions from the listings of questions provided in the lesson plan for Unit 15, Lesson 2.

   The listing of questions in the lesson plan is grouped according to unit of instruction. Only questions from the units of instruction included in the course as presented should be used in structuring the post-course assessment examination. An answer sheet and grading key should be prepared.

2. Reproduce sufficient copies of the post-course assessment examination and answer sheets to distribute to trainees.

Instructional Approach: Written examination

Presentation Options for the Course Director: Little variation in the *Closing* unit of instruction is possible.

Summary of Unit of Instruction 15: Closing

LESSON TITLE AND TIME	MAJOR LESSON OBJECTIVES	KEY POINTS AND CONTENT	INSTRUCTOR'S APPROACH	MATERIALS
1. Course Summary 30 minutes	1. Summarize the Process of Troubleshooting and its application to problem solving in wastewater treatment facilities	1. The process of troubleshooting	1. Illustrated lecture	1. *Instructor Notebook*, pages 15.1.1-15.1.6
	2. Award Certificates	2. Characteristics of a successful troubleshooting project	2. Certificate Awards	2. Certificates of Completion for each trainee (to be provided by the Course Director)
2. Trainee Post-Course Assessment	1. Demonstrate achievement of course objectives	1. Written examination covering course content	1. Written examination	1. Trainee Post-Course Examination (to be prepared by Course Director from the listing of questions provided in the *Instructor Notebook*) 2. Answer sheets (to be prepared by the Course Director) 3. Grading Key (to be prepared by the Course Director)

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 15: Closing

Lesson 1: Course Summary

Lesson 1 of 2 lessons — Recommended Time: 30 minutes

Purpose: Summarize the *Process of Troubleshooting* and discuss its application to problem solving in wastewater treatment facilities.

Trainee Entry Level Behavior: The trainee shall have achieved the learning objectives specified for Units of Instruction 1 - 14.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will be able to describe the process of troubleshooting and explain how it is applied to problem solving in wastewater treatment facilities.

Instructional Approach: Illustrated lecture.

Lesson Schedule: The 30 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 5 minutes	Purpose and Objectives of Course
5 - 10 minutes	The Process of Troubleshooting
10 - 15 minutes	Review of Lesson Subjects
15 - 30 minutes	Course Critique and Evaluation

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T1.1.3-T1.1.4, "Course Objectives."
2. *Trainee Notebook*, page T2.2.8, "The Process of Troubleshooting."
3. *Trainee Notebook*, pages T2.1.1-T2.1.2, "Notes on Troubleshooter Behavior."

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 15, Lesson 1, pages 15.1.1 - 15.1.6 .
2. "The Process of Troubleshooting" wall chart.

Instructor Materials Recommended for Development: The instructor may elect to develop a written course evaluation form for use with this lesson.

Additional Instructor References: None

Classroom Set-Up:

a. Large room, preferably 40' x 40', set in "herring bone" or "U" shape with table and chair seating for 32 trainees.

b. Instructor table with lectern.

c. Large projection screen (6' x 6' minimum) and chalkboard in front of room readily visible to all trainees.

d. Easel with pad.

e. 35mm carousel projector with remote control changer at instructor table.

f. At least four empty carousel trays.

g. Overhead projector.

h. Chalk, felt-tip markers, erasers, etc.

i. Six to eight chairs randomly spaced at back and sides of room for visitors.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
I. Purpose and Objectives of Course (5 minutes)	Guide: The Course Director or Instructor should review the objectives of the course as a means of summarizing, and seeing whether or not the course has accomplished its purpose.
A. Review with the class, briefly, the course objectives and purposes as provided in the *Trainee Notebook*, pages T1.1.3-T1.1.4.	
B. Review with class the intended level of accomplishment "At the completion of this course, students will be able to," *Trainee Notebook*, page T1.1.3.	
C. Discuss briefly the fact that the content of all the intervening lessons was designed to meet the stated objectives, and, depending on how well you've done in presenting the course, you believe that the trainees are now able to perform their job functions in a manner such that they will meet the intended level of accomplishment resulting from the course. Emphasize that the course is only a beginning - Trainees must follow through with self-study and practice in using the course materials.	Key Point: Trainees completing this course should be more effective at troubleshooting and providing technical assistance.
D. Briefly call for comments and discussion on the course objectives.	
II. The Process of Troubleshooting (5 minutes)	
A. Review the Process of Troubleshooting - note that it provided the thread that linked the various lessons and components of the course.	Refer class to Process of Troubleshooting Chart, *Trainee Notebook*, page T2.2.8.
B. Using *Trainee Notebook* pages T2.1.1-T2.1.2, review the following:	
1. Definition of Troubleshooting:	
2. Troubleshooting is a Process Which:	
3. Troubleshooting Goals Include:	Key Point: Stress the value of human skills in Troubleshooting
4. Troubleshooters are:	
5. Characteristics of Good Troubleshooter Behavior:	
C. Briefly call for comments and discussion relating to the Process of Troubleshooting.	

LESSON OUTLINE

III. Review of Lesson Subjects (5 minutes)

A. Elements of Troubleshooting

1. Human attitudes and behavior in troubleshooting

2. The importance of a systematic approach

B. Sewer Use Control

1. Importance of sewer use control and industrial pre-treatment

2. Troubleshooter's role in solving problems "outside the plant"

C. Pre/Primary Treatment

1. The importance of pretreatment to overall plant performance

2. The value of visual observations and lab tests

D. Fixed Media Systems

1. Understanding the basic properties and expected performance of a treatment process

2. Special problems in dealing with small plants

E. Oxidation Lagoons

1. Application of the systematic process of troubleshooting to solving plant problems

2. The opportunity for "creative troubleshooting" solving problems with a "hands-on" approach

F. Laboratory Practices

1. The value of the lab in process control and in troubleshooting plant problems

KEY POINTS & INSTRUCTOR GUIDES

Guide: It is not possible to thoroughly review the content of each lesson. The outline provides one or two Key Points associated with each lesson which the instructor can touch on as a summary to the course.

G. Flow Measurement

1. The importance of gauging plant flows as a key to understanding plant operation

H. Chemical Additions

1. Factors considered in applying chemicals and the consequences
2. Importance of understanding expected plant performance before troubleshooting

I. Management Behavior

1. The importance of management as a key to plant operations
2. The use of management systems on a treatment plant

J. Activated Sludge

1. Process control concepts
2. Use of the Process of Troubleshooting to solve problems

K. Solids Handling

1. Communications problem between engineers and operators
2. Plant failure due to improper solids handling

L. Land Treatment

1. Similarity of land application of sludge and effluent

M. Disinfection

1. Applicability of chlorine and ozone to a variety of plant uses
2. Troubleshooter must know the properties and hazards of chlorine and ozone.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDES
	Guide: If any time remains, call for questions or discussion.
IV. Course Critique and Evaluation (15 minutes)	
A. Seek class feedback on the course which will help you in planning and conducting future courses.	
B. Distribute and have class complete a formal evaluation of the course using your own evaluation form.	Note: Written evaluation form not included in the course materials. Use you own form or develop a form for use in the evaluation. Written evaluation is optional.

TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT FACILITIES

Unit of Instruction 15: Closing

Lesson 2: Trainee Post-Course Assessment

Lesson 2 of 2 lessons   Recommended Time: 30 minutes

Purpose: Measure trainee achievement of course objectives.

Trainee Entry Level Behavior: The trainee should have completed Unit of Instruction 15, Lesson 1, before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson, the trainee will have demonstrated his/her achievement of the course objectives by completing a written examination.

Instructional Approach: Written examination.

Lesson Schedule: The thirty minutes should be allocated for the trainees to complete the written examination.

Trainee Materials Used in Lesson: Post-Course Trainee Assessment and answer sheets are to be prepared by the Course Director for distribution to the class.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, Unit 15, Lesson 2, pages 15.2.1 - 15.2.12.
2. Post-Course Trainee Assessment and answer sheets to be prepared by the Course Director

Instructor Materials Recommended for Development: Post-Course Trainee Assessment and answer sheets.

Additional Instructor References: Instructor Notebook, Units of Instruction 1 - 14.

Classroom Set-Up: As specified for Unit 15, Lesson 1.

I. Prepare Post-Course Trainee Assessment

   A. Using the learning objectives specific for each Unit of Instruction and its component lessons, develop examination questions to measure attainment of course and lesson objectives.

   B. The following pages list questions which have been used by the Course Developers. You may select your Post-Course Assessment questions from those provided or prepare your own.

   C. It is suggested that the Post-Course Assessment be an open book, open notes examination.

II. Suggested Questions

   A. *Unit of Instruction 1: Overview*

      1. Define troubleshooting.

      2. Explain the role of troubleshooting in the national effort to control water pollution.

      3. List five factors which have been identified as contributing to poor plant performance and describe the troubleshooter's role in dealing with each factor.

   B. *Unit of Instruction 2: Elements of Troubleshooting*

      1. List the five principal elements in the process of troubleshooting. Briefly discuss the significance of each element in troubleshooting a plant problem.

      2. Describe how you will use the process of troubleshooting in your job.

      3. Compare and contrast "good" and "bad" troubleshooter behavior by citing three examples of "good" and "bad" troubleshooter behavior and explain why troubleshooter behavior is important.

      4. Explain why it is important to set objectives or goals for a troubleshooting project. Cite three examples of typical troubleshooting project goals or objectives.

      5. Explain how the troubleshooter's role differs from that of the plant operator.

C. *Unit of Instruction 3: Sewer Use Control*

1. Explain why sewer use control is important to achieving good plant performance.

2. List three examples of collection system problems which may contribute to poor plant performance and explain how each may affect plant performance.

3. Describe the basic elements of an industrial waste survey.

4. Explain how the troubleshooter can assist the plant operator in evaluating and/or improving the sewer use control program.

D. *Unit of Instruction 4: Pre/Primary Treatment*

1. Describe the purposes and functions of preliminary and primary treatment.

2. What is flow equalization? Describe how the troubleshooter can use flow equalization in problem solving.

3. List three common operational problems in primary treatment and describe how you would apply the process of troubleshooting to identify the cause and preferred solutions to each problem listed.

E. *Unit of Instruction 5: Fixed Media Systems*

1. What are fixed media biological systems?

2. List three possible causes of ponding in trickling filters and describe how you would use the process of troubleshooting to isolate the most probably cause.

F. *Unit of Instruction 6: Oxidation Lagoons*

1. Describe how the operation of a multi-cell oxidation lagoon should be changed seasonally to maintain acceptable effluent quality.

2. Describe how the operator of an oxidation lagoon can vary the operating liquid depth to improve the quality of the discharge.

3. As a troubleshooter you suspect that an oxidation lagoon is "short circuiting." Describe the laboratory tests you would run to determine if short-circuiting is the problem. Describe what you would do to cure the short-circuiting problem.

G. *Unit of Instruction 7: Laboratory Practices*

1. Describe how you would apply the process of troubleshooting to evaluation of laboratory adequacy.

2. Why is it important to distinguish between process control and effluent monitoring testing in the laboratory?

3. List three references which would be useful to you in evaluating the laboratory.

4. What is meant by the term "laboratory quality control"? Describe three ways a laboratory director might check the accuracy of the lab's testing procedures.

H. *Unit of Instruction 8: Flow Measurement*

1. List four components of a flow measurement and recording system.

2. Describe how inadequate flow measurement may affect the operator's ability to control the treatment plant.

3. Describe three ways to estimate flow rates if flow meters are missing or are inoperable.

4. When you arrive at the treatment plant, you discover that the Parshall flume and its flow indicator/recorder have not been calibrated or checked in over three years. What do you do?

I. *Unit of Instruction 9: Chemical Additions*

1. Describe three ways in which chemicals may be used to upgrade the performance of a wastewater treatment plant. What results would you expect to see? What problems may be created by using chemicals?

2. Describe the jar test and explain how the jar test may be used in troubleshooting.

J. *Unit of Instruction 10: Management Behavior*

1. Define the terms "management skill" and "management system". Cite three examples of each.

2. Explain why the troubleshooter can deal with a problem in "management systems" more easily than with a "management skills" problem.

3. List and define five management functions.

4. List and describe the components of a complete maintenance management system.

5. Describe how you could use the management audit checklist in helping a plant solve its O & M problems.

6. List five management systems and explain how a deficiency in each could impact plant performance.

7. List the management factors external to the treatment plant which could affect plant operations and describe the troubleshooter's role in dealing with such external factors.

K. *Unit of Instruction 11: Activated Sludge*

1. State the activated sludge process objective.

2. What are the controllable variables in the activated sludge process?

3. What is sludge quality? List five things which may affect sludge quality and describe the effect of each on sludge quality.

4. Define the following activated sludge process control parameters:

    a. F/M
    b. MCRT
    c. Respiration Rate
    d. Sludge Settleability

5. Assume that an activated sludge plant has a good quality normal sludge. Describe how the following changes in process conditions would affect sludge quality.

    a. Increase in return sludge flow rate
    b. Increase in influent flow rate
    c. Increase in organic load
    d. Increase in sludge wasting rate
    e. Decrease in return sludge flow rate
    f. Decrease in influent flow rate
    g. Decrease in organic load
    h. Decrease in sludge wasting rate
    i. Change operating mode to sludge reaeration
    j. Place a second aeration basin into service

6. Explain why activated sludge process control decisions should be based on combined data from the four parameters, F/M, MCRT, Respiration Rate and Sludge Settleability, rather than on data from a single parameter.

7. Describe how respiration rate measurements can be used to monitor the influent load to an activated sludge plant.

8. The load factor, the ratio of the fed sludge respiration rate to the unfed sludge respiration rate, is less than 1.0. What does this indicate?

9. Circle the correct answers in the following:

   a. A young sludge is usually associated with:

      1) A high low respiration rate
      2) A long short MCRT
      3) A slow fast settling rate
      4) Relatively unstable stable conditions
      5) A high low F/M

   b. An old sludge is usually associated with

      1) A high low respiration rate
      2) A long short MCRT
      3) A slow fast settling rate
      4) Relatively unstable stable conditions
      5) A high low F/M

10. Define sludge bulking.

11. A conventional activated sludge plant is designed to treat an average daily flow of 1.0 MGD and a peak daily flow of 1.5 MGD. The following data about the plant are available:

Chemical Analyses (24 hour composite samples, values in mg/l)

	BOD	TSS	VSS	NH_3	PO_4	pH	DO	Alkalinity
Raw	205	250	215	18	5.3	6.8	3.5	157
Pri. Eff.	130	125	125	18	5.1	6.8	2.0	157
Sec. Eff.	80	75	75	16	5.1	6.7	0.2	146

Field Observations:

Actual Flow Rate: 1.1 MGD
Aeration Volume: 300,000 gallons
MLSS Concentration: 1.1% by centrifuge
650 mg/l gravimetric analysis
Settling Test: 780 ml after 30 minutes with dispersed floc above the sludge-water interface
MLSS RR: 54 mg O_2/hr/gm
Aeration Basin D.O.: 0.5 mg/l
MLSS Color: Sandy brown
RSF: 0.5 MGD
WSF: 35,000 gpd

a. Describe how you would apply the Process of Troubleshooting to analyze the performance of this plant.

b. Identify the problem(s). What additional data, if any, are needed to identify the problem(s)?

c. List the possible causes of the problem(s). What additional data, if any, are needed to identify the causes of the problem(s)?

d. What is the most likely cause(s) of the problem(s)? What additional data, if any, are needed to confirm the most likely cause(s)?

e. What corrective action(s) do you recommend to cure the problem(s)? Why do you recommend this solution?

12. Define final clarifier solids flux. What are the components of solids flux? Why is the solids flux significant to the troubleshooter?

L. *Unit of Instruction 12: Solids Handling*

1. Describe the operation of an anaerobic digester by comparing it to the human stomach.

2. Explain why the VA/ALK ratio is the preferred parameter for controlling anaerobic digesters.

3. Describe how to "lime" a digester.

4. Three possible causes of a digester upset are (a) hydraulic overload, (b) organic overload and (c) toxic load. Describe how you would use the process of troubleshooting to determine which of the three actually caused the upset condition.

5. List three aerobic digester operational problems and describe how you would troubleshoot each problem.

6. List three processes for dewatering sludge and describe the operation of each.

M. *Unit of Instruction 13: Land Treatment*

1. Describe three ways to apply secondary effluent to land.

2. Compare and contrast land application of effluent and sludge.

3. List four factors which indicate problems in a land application system and describe the significance of each.

4. Explain how the county extension agent could provide technical assistance in evaluating a land application system.

N. *Unit of Instruction 14: Disinfection*

1. Describe the health and safety hazards associated with chlorine.

2. List the safety equipment which should be available when working with chlorine.

3. List the first aid procedures for chlorine exposure.

4. How would you detect a chlorine leak?

5. You are troubleshooting a plant with an effluent which has a high and erratic chlorine demand. What might cause this problem and how do you cure it?

O. Total Course: True-False Questions

The following set of 55 True-False questions may be used to quickly test specific information about key points covered in each unit of instruction. Questions are keyed to the unit of instruction and the correct answers are given.

1. Plant logs and records are the most reliable sources of information for the troubleshooter. (Unit 1, F)

2. A wastewater treatment plant is a unique enterprise with unique management problems. (Unit 10, F)

3. Although problems with solids in treatment plants are frequent, they seldom lead to trouble. (Unit 12, F)

4. Modification of design is the most effective alternative for upgrading oxidation lagoons. (Unit 6, F)

5. The activated sludge process varies in size, offers flexibility, produces high quality effluent and requires little or no process controls. (Unit 11, F)

6. Laboratory practices can cause as well as help to solve many treatment plant problems, (Unit 7, T)

7. The purpose of pretreatment is to prepare inflowing wastewater in order to maximize downstream plant performance. (Unit 4, T)

8. Climate is a factor in considering the performance of a trickling filter plant. (Unit 5, T)

9. The overall objective of this course has been to improve the enforcement aspects of PL 92-500. (Unit 1, F)

10. Generally, chemical additives are used at conventional plants for odor control. (Unit 9, F)

11. A "stuck" or "sick" digester can be described as doing the same things as an upset stomach. (Unit 12, T)

12. Improving the chlorine diffuser system is one method of upgrading chlorine contact tanks. (Unit 14, T)

13. Sludge age is defined as the pounds of suspended solids in the aeration system divided by pounds of suspended solids in the primary effluent per day. (Unit 11, T)

14. The four elements of a land treatment system are a) weather, b) land area, c) distribution and d) transportation. (Unit 13, F)

15. A rising sludge blanket should alert the troubleshooter to a "septic" condition (Unit 11, F)

16. The troubleshooter should characterize "flows" as linkages between plant processes. (Unit 8, T)

17. The most common sludge problems in the activated sludge process are "sludge age" and "sludge quantity." (Unit 11, T)

18. Visual observations of pumps and meters for indicators of operational problems is applicable to troubleshooting the activated sludge treatment process. (Unit 11, T)

19. Troubleshooting is defined as the practice of problem solving. (Unit 2, T)

20. Flow and recirculation rates are useful tests for troubleshooting trickling filters. (Unit 5, T)

21. Troubleshooting problems with anaerobic digestion should include a study of piping, pumping, heating and process controls. (Unit 12, T)

22. According to a national survey of treatment facilities, more than half of secondary facilities are meeting secondary effluent requirements. (Unit 1, F)

23. The troubleshooter may need to analyze sludge content in problems involving land treatment. (Unit 13, T)

24. A plant which has recently received an NPDES permit will not require troubleshooting. (Unit 1, F)

25. With a knowledge of management systems, troubleshooters should be able to provide assistance to the operator and/or plant superintendent. (Unit 10, T)

26. A white foam on the aeration tank surface usually indicates a young sludge and high solids. (Unit 11, F)

27. It is important for the troubleshooter to distinguish between various uses of a plant lab. (Unit 7, T)

28. The troubleshooter should recommend operating mechanical scrapers less frequently to correct a "floating sludge" problem. (Unit 4, F)

29. Part-time operators are usually less effective because they are too busy to care about plant operations. (Unit 5, F)

30. To control periodic pollutant overloads the troubleshooter may wish to recommend the use of coagulants. (Unit 9, T)

31. The troubleshooter should personally try to maintain control over plant operations. (Unit 2, F)

32. Obvious "dry labbing" is an indicator of management problems. (Unit 10, T)

33. Ozone, lime and powdered potassium are good alternatives to chlorine for odor control. (Unit 14, F)

34. Since no two activated sludge systems are alike, skill in troubleshooting activated sludge plants is best achieved through experience. (Unit 11, T)

35. In addition to anaerobic digestion, the only type of solids handling process are gravity thickening, sludge drying beds and vacuum filtration. (Unit 12, F)

36. For above ground surface lines, electro-chemical corrosion should be corrected with plastic pipe. (Unit 13, F)

37. Before effective troubleshooting of activated sludge plants can begin, operating and design data should be analyzed (Unit 11, T)

38. Organic overload and toxics are causes of high BOD and/or suspended solids which can be controlled by the troubleshooter (Unit 11, F)

39. Hydrogen sulfate (H_2SO_4) should be used as a preservative for samples containing metals. (Unit 7, F)

40. In flow measurement, the three types of "constrictors" are: a) flumes, b) pumps and c) weirs. (Unit 8, F)

41. One of the characteristics of an aerated lagoon is that it requires a depth of between 10 and 20 feet. (Unit 6, T)

42. Sludge drying beds are probably used more than any other method of sludge dewatering. (Unit 12, T)

43. Chemical coagulants are less difficult to troubleshoot than conventional operations. (Unit 9, F)

44. The troubleshooter should not hesitate to serve as a management consultant when he observes plant management problems. (Unit 10, F)

45. Troubleshooters generally need not be concerned with "marginal performers" since new construction should be recommended. (Unit 1, F)

46. Land renovation areas usually have minor problems and little or no soil erosion problems. (Unit 5, F)

47. "Upgrading" a trickling filter plant means to increase its size. (Unit 13, F)

48. Sludge bulking is usually created from biological causes.(Unit 11, F)

49. A jar test is an acceptable method for determining dissolved oxygen in the primary treatment process. (Unit 4, F)

50. Because chlorine is a colorless, hard-to-detect gas, a gas mask should always be kept inside the chlorine room. (Unit 14, F)

51. The troubleshooter should generally avoid discussing plant problems with various plant personnel. (Unit 1, F)

52. Assuring the plant operator of your expertise about his plant is an important first step. (Unit 2, F)

53. Normally, the expected performance of oxidation lagoons won't meet secondary effluent requirements. (Unit 6, T)

54. High drum speed, high feed rate and low vacuum are typical causes of "thin cake" problems when troubleshooting vacuum filters. (Unit 12, F)

55. An activated sludge "package plant" is defined as a self-contained plant that can be transported to a site and handle flows for approximately 50,000 people. (Unit 11, F)

P. Appropriate Muntiple Choice Questions may be selected from the seventy-five questions in the Trainee Assessment included in Unit of Instruction 1, Lesson 2.

PL 92-500 (1972) AND PL 95-217 (1976)

GOALS:

- NO DISCHARGE BY 1985.
- FISHABLE AND SWIMMABLE WATERS BY 1983

NATIONAL WATER QUALITY CONTROL

PROGRAM ELEMENTS

- WATER QUALITY STANDARDS
- AREAWIDE PLANNING
- CONSTRUCTION GRANTS
- NPDES PERMITS

179.2/

TO MAKE NPDES WORK–WE NEED

- ADEQUATE TREATMENT FACILITIES
- EFFICIENT PLANT OPERATIONS
- MONITORING AND INSPECTION
  - FEDERAL
  - STATE
  - LOCAL

USES OF MONITORING AND INSPECTION FINDINGS

- EVALUATION:

  LOCAL,STATE,FEDERAL

- CORRECTIVE ACTION:

  LOCAL

- ENFORCEMENT:

  FEDERAL,STATE

179.2/1.

POLLUTION CONTROL PERSONNEL

MUST BE ABLE TO:

- EVALUATE PLANT PERFORMANCE
- IDENTIFY PERFORMANCE DEFICIENCIES
- DETERMINE CAUSES
- RECOMMEND CORRECTIVE ACTION
- IMPLEMENT CORRECTIVE ACTION
- FOLLOW-UP CORRECTIVE ACTION

COURSE PURPOSES

- TRAIN IN PROCESS OF TROUBLESHOOTING
- REVIEW PLANT OPERATIONS
- APPLY PROCESS OF TROUBLESHOOTING TO REALISTIC PROBLEMS
- STRESS COOPERATIVE RELATIONSHIPS
- IMPROVE COMMUNICATIONS SKILLS

OWNERS ROLE

- OPERATE PLANT
- ACCEPT TECHNICAL ASSISTANCE
- TRAIN STAFF
- FUND IMPROVEMENTS
  - OPERATIONAL
  - FACILITY MODIFICATION

STATES ROLE

- FIELD PERSONNEL
  - INSPECTION
  - MONITORING
  - TECHNICAL ASSISTANCE
- OPERATOR TRAINING & CERTIFICATION
- COMPLIANCE ASSURANCE
  - ISSUE PERMITS
  - ENFORCEMENT
  - ASSISTANCE
- CONSTRUCTION SUPPORT
  - PLANS & SPECS REVIEW
  - GRANTS

179.2/1.3.9

FEDERAL ROLE

- TECHNICAL ASSISTANCE
    - PROGRAM GUIDANCE
    - TECHNICAL MANUALS
    - TRAINING
- CONSTRUCTION SUPPORT
    - GRANTS
    - DESIGN GUIDANCE
    - O&M MANUALS
- COMPLIANCE ASSURANCE
    - GUIDANCE
    - INSPECTION
    - TECHNICAL

CONSULTANT'S ROLE

*DESIGN

*START-UP

*TECHNICAL ASSISTANCE

*OPERATIONAL SERVICES

DEFINITION OF TROUBLESHOOTING

TROUBLESHOOTING IS THE PRACTICE
OF PROBLEM SOLVING APPLIED TO AN
EXISTING FACILITY IN USE AND EXPERIENCING
OPERATIONAL PROBLEMS WHICH AFFECT ITS PERFORMANCE

SOLVING TREATMENT PLANT PROBLEMS

OPERATOR	TROUBLESHOOTER
DIRECT CONTROL OVER PLANT OPERATIONS	INDIRECT ROLE USES EXPERIENCE TO ASSIST

179.2/2.1.4

TROUBLESHOOTER RELATIONSHIPS

OPERATOR

HUMAN SKILLS:

- ATTITUDE
- JUDGEMENT
- SINCERITY
- FRIENDLINESS

PLANT

TECHNICAL SKILLS:

- EXPERIENCE
- PROCESS CONTROL
- LOGIC
- TECHNICAL "KNOW HOW"

FOR EACH PLANT - TROUBLESHOOTER MUST UNDERSTAND

- PLANT ORGANIZATION - RELATIONSHIP OF PERSONNEL
- EXTERNAL COMMUNITY CONDITIONS
- PAST PLANT PERFORMANCE
- PLANT OPERATIONS AND PROCESSES
- ENVIRONMENTAL AND REGULATORY REQUIREMENTS - EPA, STATE, LOCAL

179.2/2.1.6

TROUBLESHOOTING GOALS

- REPAIRING BREAKDOWN OR IMMEDIATE PROBLEM
- PREVENTING RECURRENCE OF PROBLEM
- IMPROVING LONG-RUN O&M
- UPGRADING OVERALL PLANT EFFICIENCY

TROUBLESHOOTERS ARE

- INVESTIGATORS
- PROBLEM SOLVERS
- MECHANICS
- PSYCHOLOGISTS
- ASSISTANTS

179.2/2.1.8

BASIC ELEMENTS OF TROUBLESHOOTING

- REVIEW OF PLANT CONDITIONS
- COMMUNICATION AND OBSERVATION
- ANALYSIS AND TESTING
- FORMULATION OF ALTERNATIVE ACTIONS
- CORRECTIVE ACTIONS - TRIAL AND ERROR
- LONG RANGE IMPLEMENTATION
- MONITOR , DOCUMENT, AND FOLLOW-UP

THE PROCESS OF TROUBLESHOOTING

ANALYZING AND LEARNING

A. BEGIN TROUBLESHOOTING

B. REVIEW INFORMATION

C. VISIT PLANT

D. DETERMINE DATA NEEDS

E. ANALYZE, SAMPLE AND TEST

F. PROCESS TEST

179.2/2.2.3

BEGIN TROUBLESHOOTING

POSSIBLE CIRCUMSTANCES OF ROUBLESHOOTER ENTRY INTO PLANT

- PART OF ROUTINE INSPECTION
- REQUEST BY PLANT OPERATOR
- COMPLAINT FROM CITIZENS
- VIOLATION OF PERMIT CONDITIONS

VISIT PLANT – MEET AND LISTEN, OBSERVE AND REVIEW

WHO SHOULD YOU MEET?

WHO SHOULD YOU LISTEN TO?

WHAT SHOULD YOU OBSERVE?

WHY??

179.2/2.2.6

FORMULATING ALTERNATIVE SOLUTIONS

A. INITIAL OPINION – DO WE KNOW THE CAUSE?

B. OPINION – REASONING LEADS TO ALTERNATIVES

C. ALTERNATIVES – CONSIDER TYPES AND IMPACT OF EACH

D. PRIORITY ALTERNATIVES

E. CONFIRM – WITH WHOM?

179.2/2.2.8

ELEMENTS OF TROUBLESHOOTING

CORRECTIVE ACTIONS

- TYPE OF ACTION TO TAKE
- PURPOSE OF ACTION
- DURATION OF THE RESULTS
- EFFECT OF ACTION
- SHOULD THERE BE A COMBINATION OF DIFFERENT ACTIONS FOR DIFFERENT PURPOSES?

OBSERVE AND TEST

- WHICH TESTS TO MAKE
- EVALUATE THE RESULTS
- COMPARE RESULTS WITH PRIOR PERFORMANCE
- ARE THE DESIRED RESULTS ACHIEVED? IF NOT - SELECT A DIFFERENT ALTERNATIVE

LONG RANGE IMPLEMENTATION

TYPES OF MEASURES POSSIBLE

- PROCESS OR FLOW CHANGES
- CHEMICAL ADDITIONS
- DESIGN MODIFICATIONS
- REPAIR OR REPLACE EQUIPMENT
- CLEANING AND MAINTENANCE
- MANAGEMENT CHANGES

179.2/2.2.11

FINAL STEPS IN THE PROCESS OF TROUBLESHOOTING

- MONITOR RESULTS

- DOCUMENT

- FOLLOW-UP

179.2/2.2.12

RESULTS SHOULD REFLECT GOALS
KNOW WHAT YOU'RE TRYING TO DO !

- SOLVE IMMEDIATE BREAKDOWN OR PROBLEM
- PREVENT RECURRENCE
- IMPROVE LONG-RUN O&M
- UPGRADE PLANT PERFORMANCE

EFFECTIVE TECHNICAL ASSISTANCE

- ACCEPTED AND UNDERSTOOD BY THE OPERATOR

- FEASIBLE, IN BOTH $ AND MANPOWER RESOURCES FOR THE PLANT

- WITHIN THE PLANT CAPACITY AND DESIGN

- OF LONG RANGE VALUE TO THE PLANT

- ???

TROUBLESHOOTING

- REQUIRES HUMAN AND TECHNICAL SKILLS
- NEEDS POSITIVE HUMAN BEHAVIOR
- MUST BE SYSTEMATIC
- CAN BE APPROACHED THROUGH THE PROCESS OF TROUBLESHOOTING
- MUST BE ACCEPTABLE AND FEASIBLE

PURPOSES OF PRETREATMENT

- PROTECT PUBLICLY OWNED TREATMENT WORKS
    - CONTINUITY OF TREATMENT
    - PHYSICAL PROTECTION
- PREVENT PASS-THROUGH
    - SATISFY NPDES PERMIT
    - PROTECT RECEIVING WATERS

PROHIBITED DISCHARGES

*FIRE OR EXPLOSIVE HAZARD

*CORROSIVE DAMAGE

*SEWER OBSTRUCTIONS

*SLUG DISCHARGES

*HEAT

CATEGORICAL STANDARDS

*INCOMPATIBLE POLLUTANTS

*21 INDUSTRIAL CATEGORIES

*65 CLASSES OF TOXIC POLLUTANTS

*TECHNOLOGY BASED STANDARDS

PROBLEMS WITH INDUSTRIAL WASTE

1. INTERFERENCE WITH TREATMENT
2. SLUDGE CONTAMINATION
3. PASS-THROUGH

179.2/3.2.5

ENFORCEMENT OF PRETREATMENT STANDARDS

- LOCAL POLLUTION CONTROL AGENCY OPERATES FACILITIES
- PRETREATMENT PROGRAM ELEMENTS
  - ENFORCEABLE LEGAL AUTHORITY
    - MONITORING
    - REPORTING
    - INSPECTIONS
    - PENALTIES
  - INVENTORY AUTHORITY
  - RESOURCES

INDUSTRIAL DISCHARGE DATA BASE

- LIST OF POTENTIAL DISCHARGERS
- PRELIMINARY ANALYSIS OF DATA
- QUESTIONNAIRE SURVEY
- DETAILED DATA ANALYSIS
- SAMPLING PROGRAMS

179.2/3.2.7

IDENTIFYING POTENTIAL DISCHARGERS

- SEWER AUTHORITY FILES
- CITY & STATE INDUSTRIAL RECORDS
- PROPERTY TAX RECORDS
- CHAMBER OF COMMERCE
- TELEPHONE DIRECTORY
- WATER DEPARTMENT RECORDS
- DUN'S MARKET IDENTIFIERS
  (DUN AND BRADSTREET)

PRELIMINARY DATA ON INDUSTRIES

*LOCATION

*SIC CLASSIFICATION

*PRODUCT LINE

*PRODUCTION VOLUME

179.2/3.2.9

PRELIMINARY DATA ANALYSIS

*MASTER LIST

*GROUP BY SIC

*WET OR DRY

*SIGNIFICANT DISCHARGER ?

*POTW SENSITIVITY TO WASTE

179.2/3.2.10

SURVEY QUESTIONNAIRE DATA

*WHO

*PRODUCTION

*EMPLOYMENT

*WATER USE

*SEWER CONNECTIONS

*DISCHARGE CHARACTERISTICS

179.2/3.2.11

ORDINANCE PROVISIONS

- AREA OF JURISDICTION
- DEFINITIONS
- PROHIBITED MATERIALS
- SPECIFIC POLLUTANTS
- AUTHORITY & PROCEDURES FOR CONTROL
- MONITORING & REPORTING
- ENFORCEMENT PROCEDURES
- PROCEDURAL CLAUSES WITH DATES
- SEVERABILITY CLAUSE

179.2/3.2.

PURPOSE AND BENEFITS OF EQUALIZATION

- DAMPEN HYDRAULIC &ORGANIC OVERLOADS
- REDUCE NEED FOR ADDITIONAL TREATMENT CAPACITY
- IMPROVE TREATMENT EFFICIENCY

179.2/4.1.4

FLOW EQUALIZATION METHODS

- USE ANY AVAILABLE STORAGE CAPACITY
  - SPARE TANK
  - UNUSED CLARIFERS
- PONDING OR HOLDING AREA
- VARY LEVELS IN DITCHES OR PONDS
  TO EQUALIZE FLOWS

179.2/4.1.5

INITIAL STEPS IN THE PROCESS OF TROUBLESHOOTING

- REVIEW KNOWN INFORMATION
- VISIT PLANT: MEET, LISTEN, OBSERVE AND REVIEW

LEARN HOW THE PLANT NORMALLY OPERATES

- FLOWS, LOAD AND BALANCE
- REMOVAL EFFICIENCY
- SLUDGE HANDLING
- MAINTENANCE AND CONDITION

179.2/4.2.

THE PROCESS OF TROUBLESHOOTING –

ANALYZE AND LEARN

- DETERMINE DATA NEEDS
- ANALYZE, SAMPLE AND TEST
- PROCESS TEST, MODIFY
  PROCESS AND ANALYZE

179.2/4.2.10

LAB TESTS – PRIMARY TREATMENT PROCESS CONTROL AND TROUBLESHOOTING

- SOLIDS
  - SETTLEABLE AND SUSPENDED
  - TOTAL
- BOD
- pH
- SPECIAL TESTS

PECIAL TESTS USEFUL IN TROUBLESHOOTING PRIMARY TREATMENT

- JAR TEST FOR CHEMICAL COAGULATION
- DISSOLVED OXYGEN
- HEAVY METALS

179.2/4.2.12

PROBLEM ANALYSIS IN PRIMARY TREATMEN

TROUBLESHOOTING FOR PROBLEM

- CAUSES
- ALTERNATIVE CORRECTIONS
- PREVENTION

179.2/4.2.

OMMON PROBLEMS – PRIMARY TREATMENT

- FLOATING SLUDGE
- SEPTIC WASTEWATER
- GROWTHS ON WEIRS
- SEDIMENT IN INLET CHANNELS

179.2/4.2.16

MORE COMMON PROBLEMS
– PRIMARY TREATMENT

- SURGING OR INTERMITTENT FLOW
- SCRAPER OR SHEAR PIN FAILURE
- SLUDGE REMOVAL FROM HOPPER
- EXCESSIVE CORROSION

FLOATING SLUDGE

- *CAUSES ?
- *ALTERNATIVE CORRECTIONS?
- *PREVENTION ?

179.2/4.2.19

SEPTIC WASTEWATER -- BLACK AND ODOROUS

- *CAUSES?
- *ALTERNATIVE CORRECTIONS?
- *PREVENTION?

179.2/4.2.20

BROKEN SCRAPER CHAINS OR SHEAR PIN FAILURES

- CAUSES?
- ALTERNATIVE CORRECTIONS?
- PREVENTION?

179.2/4.2.25

TYPES OF TROUBLESHOOTING ACTIONS RECOMMENED - PRIMARY TREATMENT

- PROCESS AND OPERATIONAL CHANGES
- EQUIPMENT REPAIR
- CLEANING AND MAINTENANCE
- CHEMICAL ADDITIONS

179.2/4.2.30

TROUBLESHOOTING ACTIONS SHOULD

- SOLVE IMMEDIATE BREAKDOWN
- PREVENT RECURRENCE
- IMPROVE LONG RUN MAINTENANCE AND PREVENTION OF PROBLEMS
- IMPROVE LONG RUN EFFICIENCY

179.2/4.2.31

TROUBLESHOOTER'S ACTIONS MUST

- RECEIVE ACCEPTANCE OF OPERATOR
- BE WITHIN FINANCIAL AND MANPOWER CAPABILITY
- KEEP PLANT WITHIN DESIGN CRITERIA
- SOLVE BOTH SHORT AND LONG RUN PROBLEMS

FINAL TROUBLESHOOTING STEPS INCLUDE

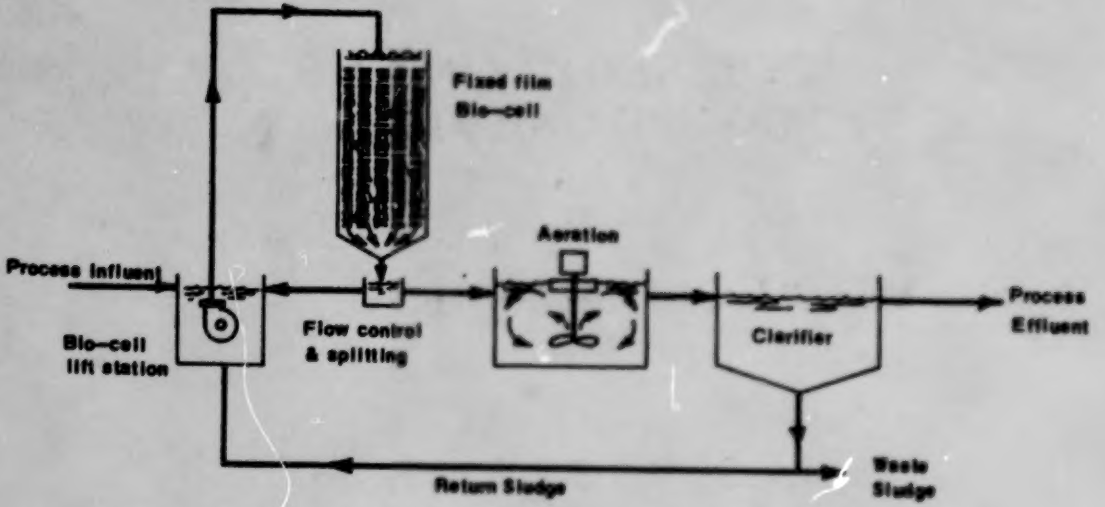
- OVERSEEING IMPLEMENTATION
- MONITORING RESULTS
- DOCUMENTING RESULTS
- FOLLOW-UP

179.2/4.2.33

TYPES OF FIXED MEDIA SYSTEMS

- TRICKLING FILTER (TF)
- ACTIVATED BIO-FILTER (ABF)
- ROTATING BIOLOGICAL CONTACTORS (RBC)

179.2/5



ACTIVATED BIOFILTER PROCESS SCHEMATIC

179.2/5.1.8

FACTORS AFFECTING FIXED MEDIA SYSTEM PERFORMANCE

- PROPER DESIGN
- CLIMATE
- CHARACTER OF WASTES
- DISTRIBUTION OF WASTEWATER OVER MEDIA
- VENTILATION
- CONDITION OF MEDIA
- PROPER UNDERBASIN SYSTEM OR FLOW PATTERN

179.2/5.1.11

COMMON RCB PROBLEMS

- HEAVY SLOUGHING OF GROWTH
- DECREASED TREATMENT EFFICIENCY
- BIOMASS TURNS WHITE
- SOLIDS ACCUMULATION IN REACTORS
- BEARINGS AND MOTOR OVERHEATING AND FAILURE

179.2/5.1.27

TROUBLESHOOTING CHEMICAL ADDITIVES

KNOW EXPECTED PLANT PERFORMANCE

OBSERVE TO COLLECT DATA

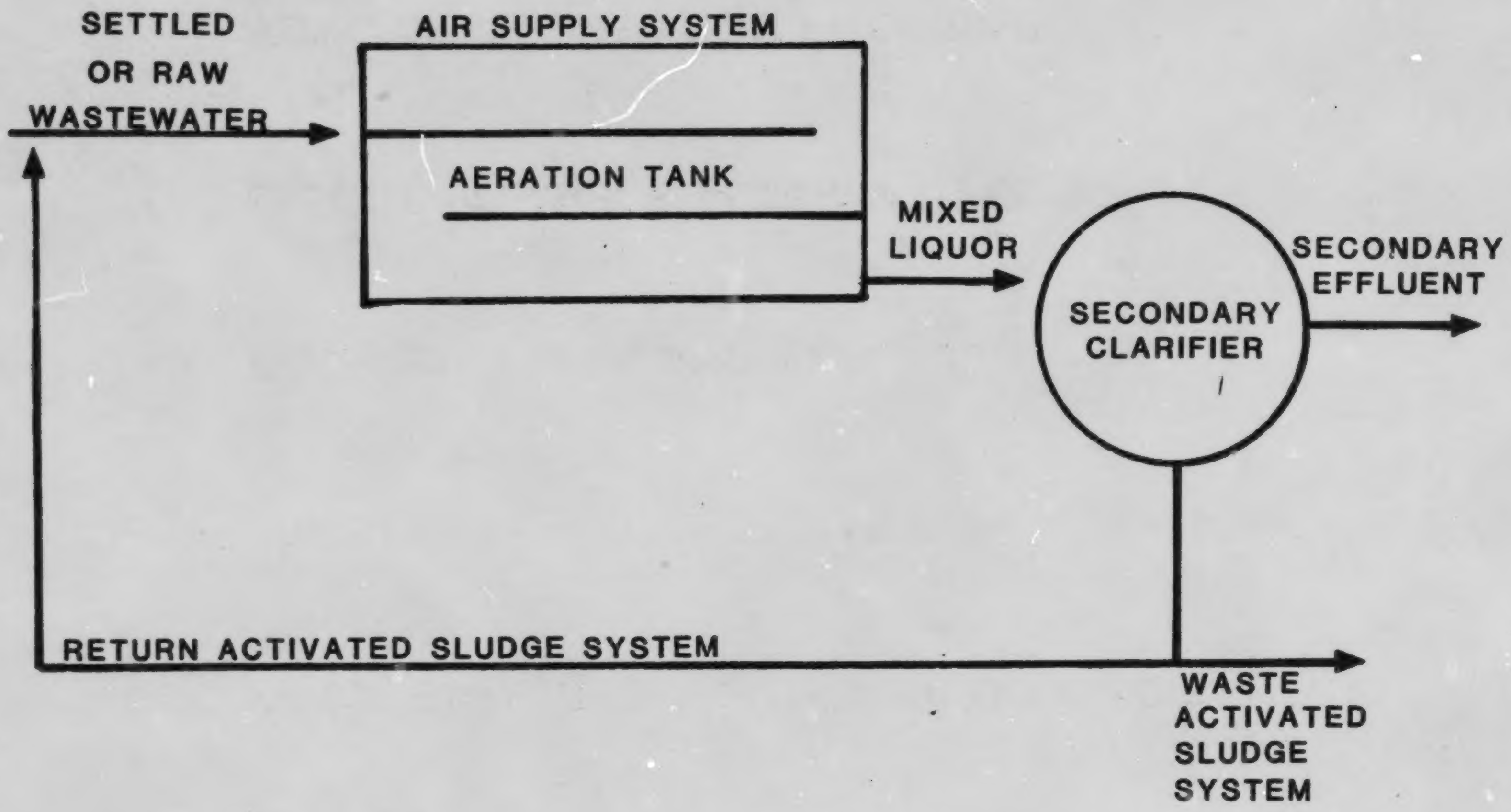
PERFORM TESTS AND ANALYSES

SELECT POSSIBLE ALTERNATIVES

MONITOR CORRECTION PROCEDURE

LONG-TERM FOLLOW-UP IS IMPORTANT !!

ACTIVATED SLUDGE SYSTEM



SETTLED
OR RAW
WASTEWATER

AIR SUPPLY SYSTEM

AERATION TANK

MIXED
LIQUOR

SECONDARY
CLARIFIER

SECONDARY
EFFLUENT

RETURN ACTIVATED SLUDGE SYSTEM

WASTE
ACTIVATED
SLUDGE
SYSTEM

ACTIVATED SLUDGE PROCESS OBJECTIVE

CONVERT NON-SETTLEABLE BIODEGRADABLE POLLUTANTS TO SETTLEABLE SOLIDS TO PRODUCE A CLARIFIED EFFLUENT LOW IN TSS AND BOD

179.2/11.1.3

SETTLEABLE SOLIDS
SLUDGE QUALITY

GOOD	BAD
* SETTLES FAIRLY RAPIDLY	* SETTLES VERY FAST OR VERY SLOWLY
* CONCENTRATES UNIFORMLY IN 30 TO 60 MINUTES	* CONCENTRATES VERY RAPIDLY (30 MINUTES) OR VERY SLOWLY (2-4 HOURS)
* FLOCCULENT	* GRANULAR OR EXCESSIVELY FLUFFY
* CLEAR SUPERNATE	* CLOUDY, TURBID, STRAGGLER FLOC, PIN FLOC OR ASHING
* DEEP TAN TO BROWN	* LIGHT TAN, VERY DARK BROWN OR BLACK

179.2/11.1.4

ACTIVATED SLUDGE OPERATOR'S OBJECTIVE

MAINTAIN ENVIRONMENTAL CONDITIONS TO MAXIMIZE CONVERSION OF NON-SETTLEABLE POLLUTANTS TO SETTLEABLE SOLIDS AND REMOVE THE SETTLED SOLID FROM THE SYSTEM SO THAT THEY CAN BE DISPOSED OF SAFELY.

179.2/11.1.5

ACTIVATED SLUDGE
OPERATOR'S FUNCTIONS

EXERCISE PROPER OPERATIONAL CONTROL OF THE SYSTEM

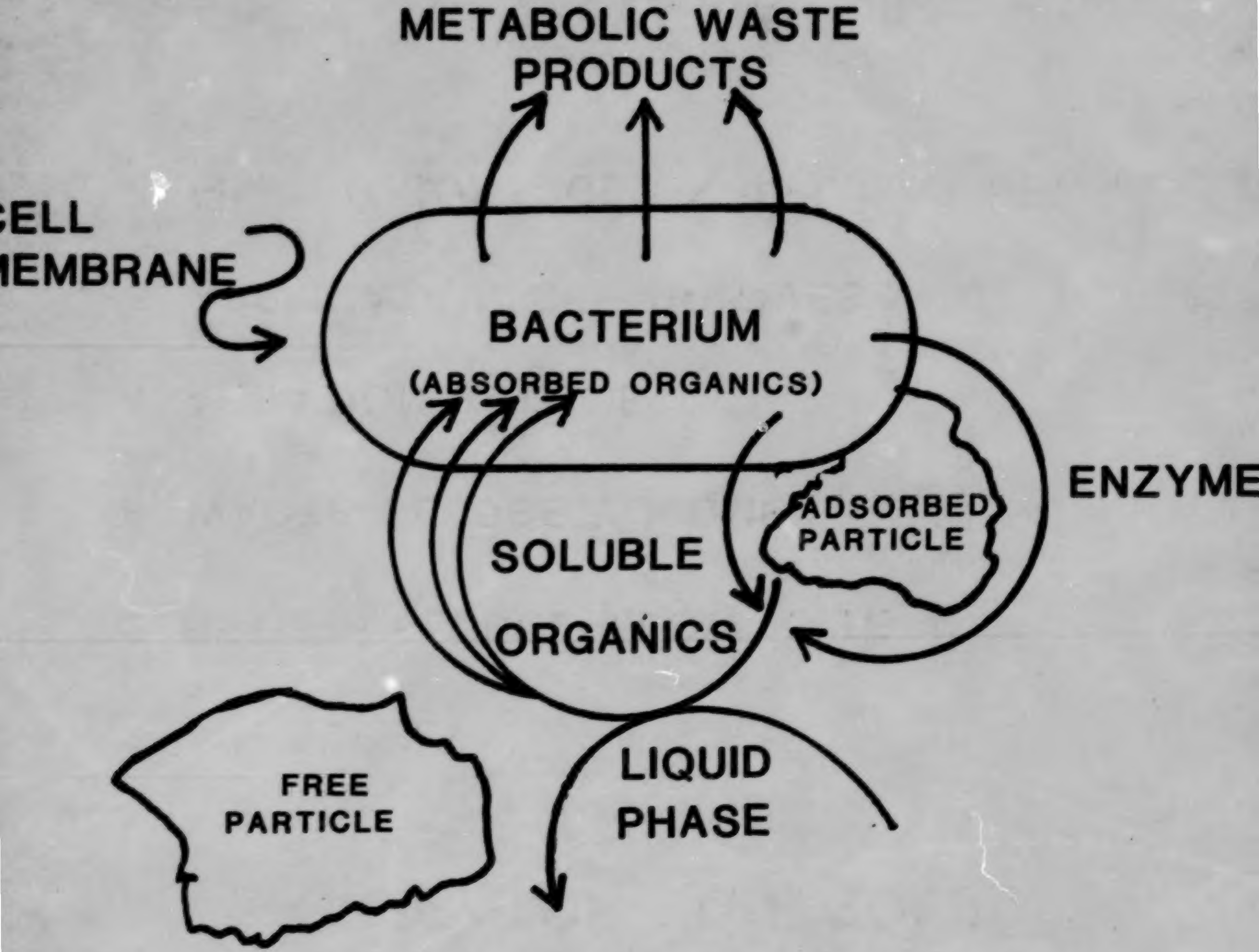
1. OBSERVATION
2. LABORATORY TESTING
3. INTERPRETATION OF RESULTS
4. ADJUST CONTROLLABLE PARAMETERS

179.2/11.1.6

OPERATOR CONTROLS

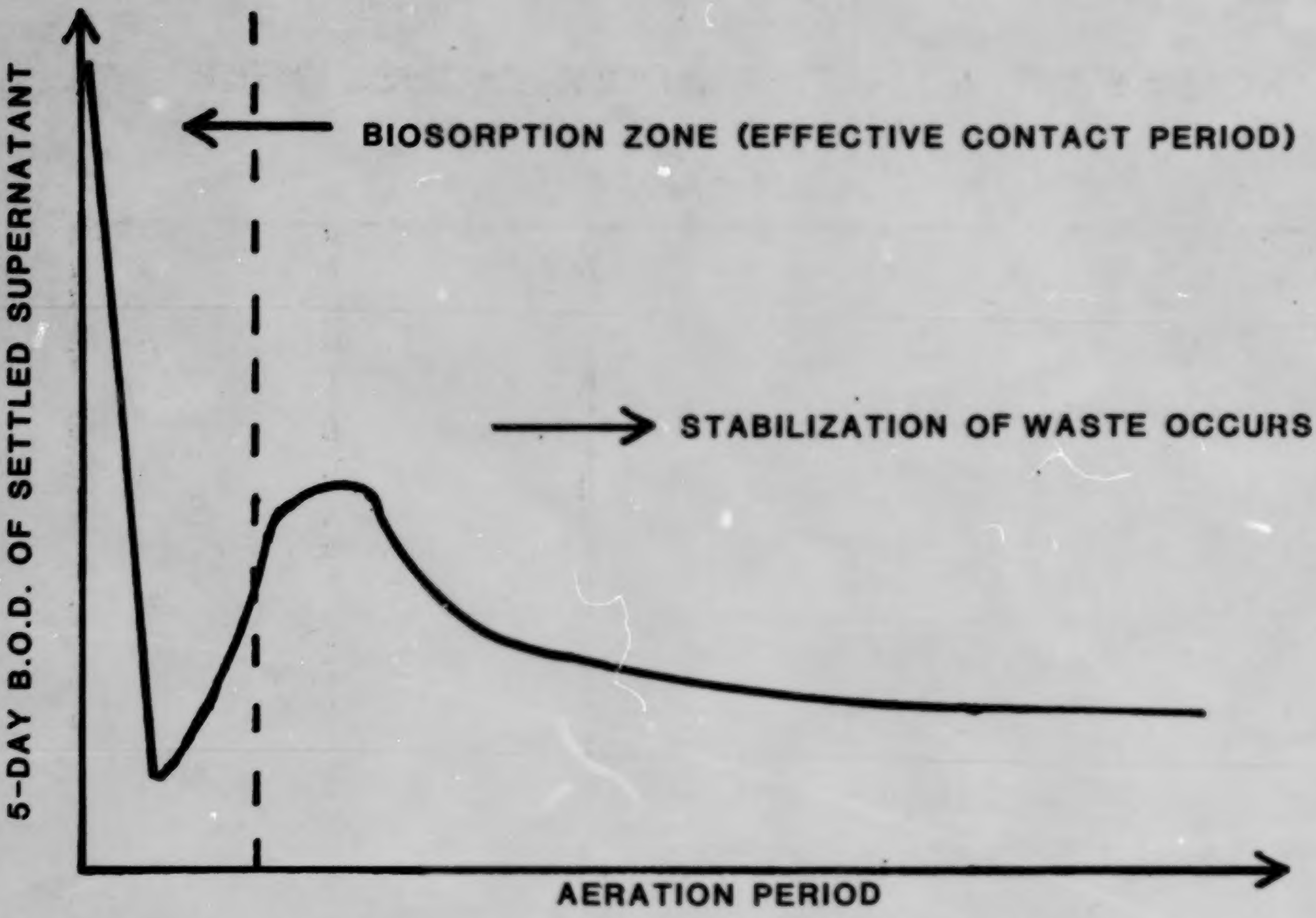
1. AIR SUPPLY
2. RETURN SLUDGE FLOW RATE
3. WASTE SLUDGE VOLUME
4. AERATION VOLUME
5. APPLICATION OF ADDITIVES
6. LIMITED CONTROL ON INFLUENT SEWAGE

179.2/11.1.7

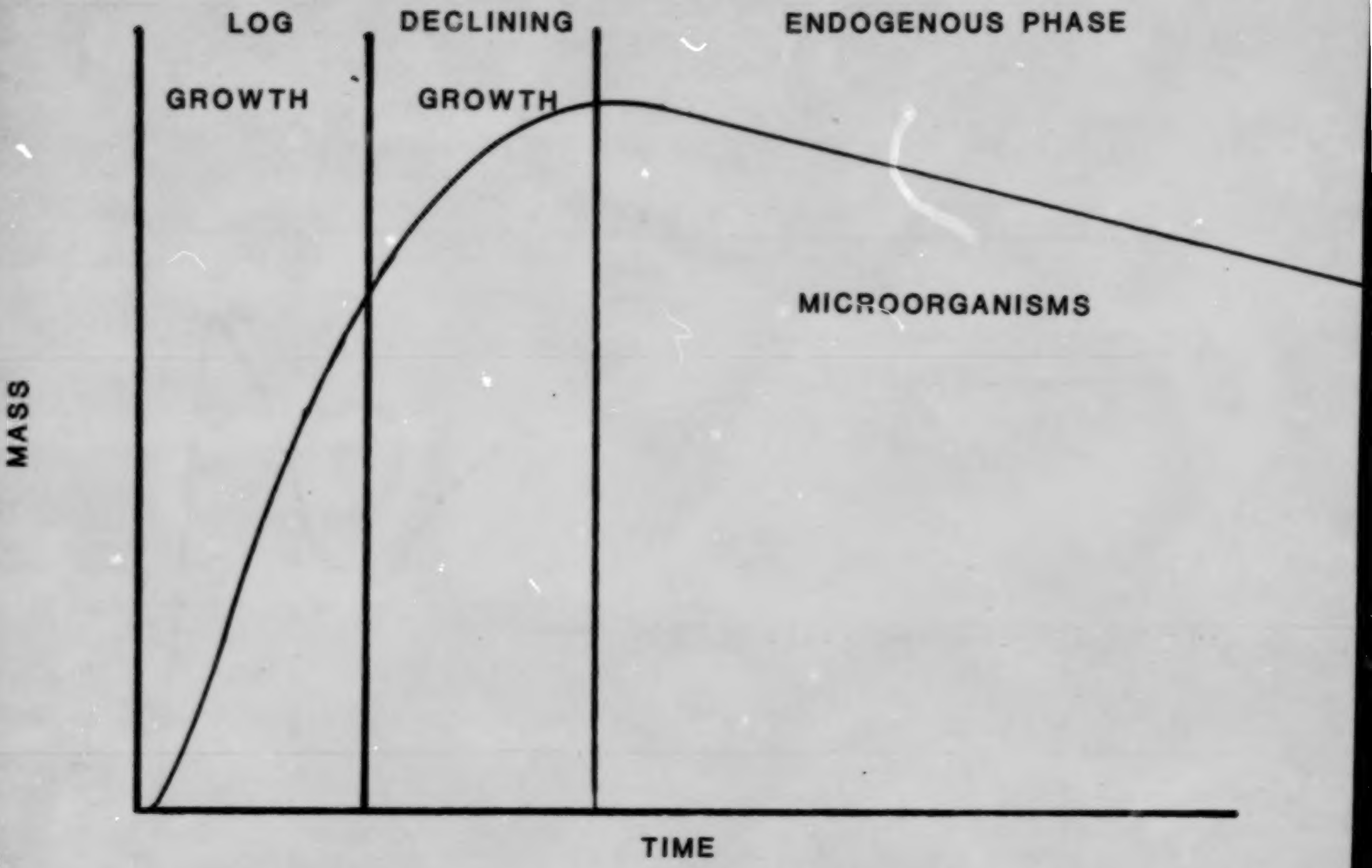


SORPTION OF DEGRADABLE ORGANICS

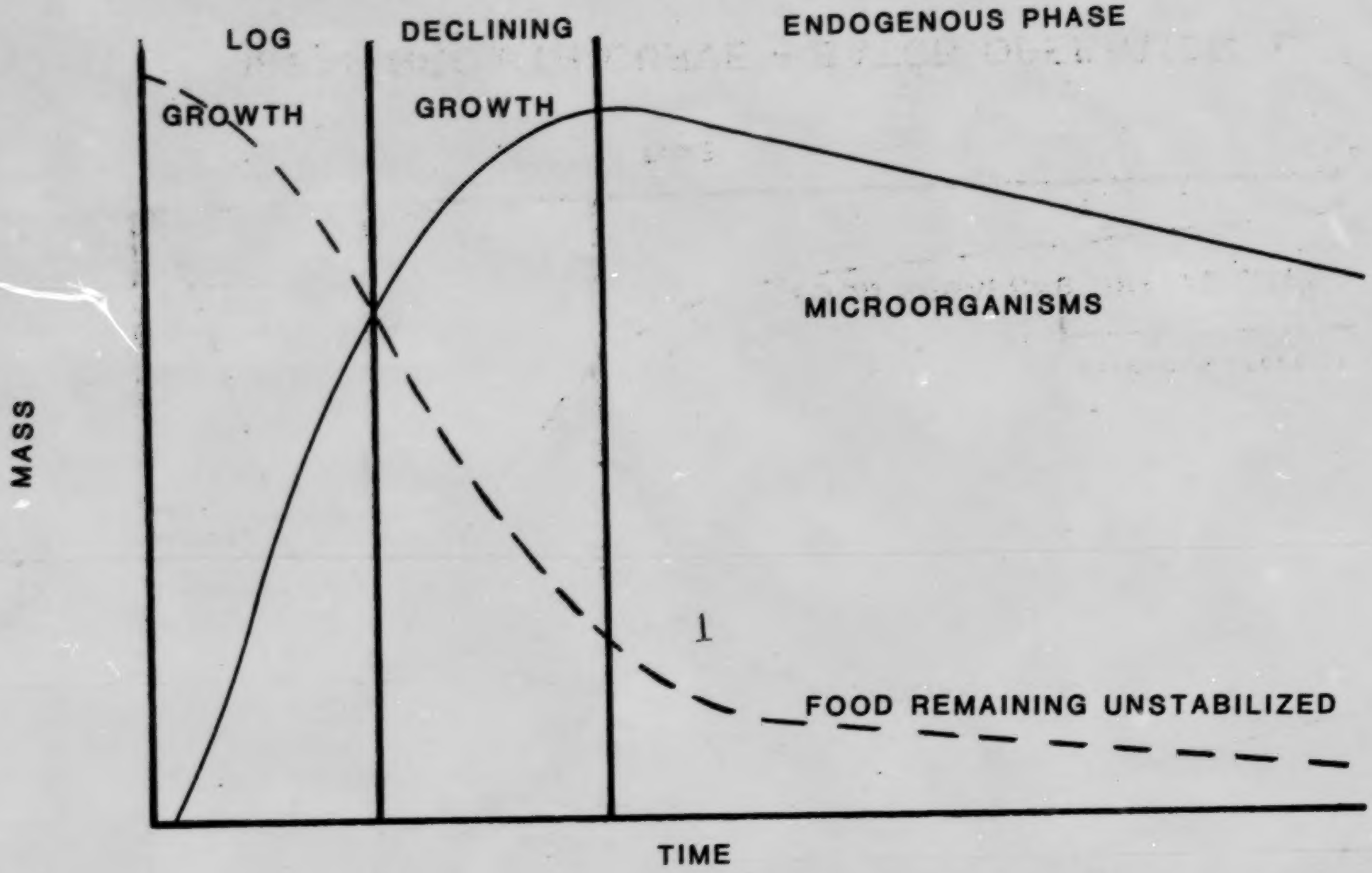
179.2/11.1.



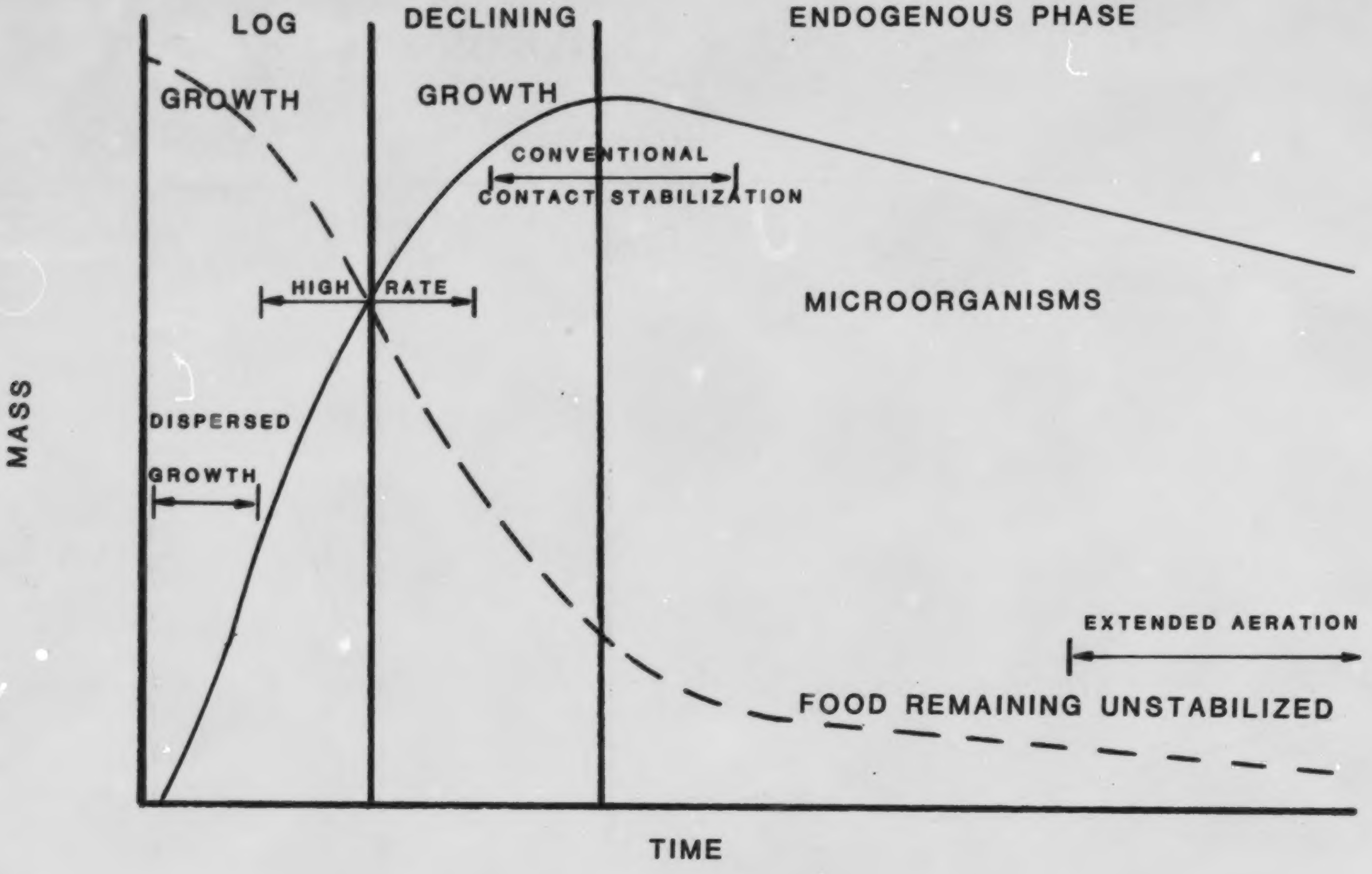
VARIATION OF 5-DAY B.O.D. OF RAW SEWAGE-ACTIVATED
SLUDGE MIXTURE WITH AERATION PERIOD



IDEAL GROWTH CURVE- BATCH OPERATION



IDEAL GROWTH CURVE - BATCH OPERATION



IDEAL GROWTH CURVE - BATCH OPERATION

179.2/11.1.12

1571

1570

GENERAL AEROBIC BIOLOGICAL REACTION

FOOD + OXYGEN + NUTRIENTS
(BOD) (D.O.) (N,P,Fe)

IN THE PRESENCE OF

MICROORGANISMS
(MLSS OR MLVSS)

GOES TO

CARBON DIOXIDE + WATER + MORE MICROORGANISMS
(CO_2) (H_2O) (EXCESS SLUDGE,
MLSS OR MLVSS)

NUTRIENT REQUIREMENTS

BOD : N - 20 : 1

BOD : P - 100 : 1

BOD : F_E - 200 : 1

179.2/11.1.14

NITRIFICATION

AMMONIA NITROGEN + OXYGEN + ALKALINITY
NH_3 D.O. AS $CaCO_3$

IN THE PRESENCE OF **NITRIFYING BACTERIA** GOES TO

NITRITE NITROGEN
NO_2^-

THEN GOES TO

NITRATE NITROGEN
NO_3^-

179.2/11.1.15

CONDITIONS FOR NITRIFICATION

4.6 # OXYGEN PER # AMMONIA NITROGEN CONVERTED

7.1 # ALKALINITY PER # AMMONIA NITROGEN CONVERTED

pH IN RANGE 7.9 - 8.9

LONG MCRT

SOME CARBONACEOUS BOD

DENITRIFICATION

NITRATE NITROGEN REDUCES
TO FREE NITROGEN GAS UNDER
ANOXIC CONDITIONS

179.2/11.1.17

SLUDGE YIELD

1 # BOD REMOVED - 0.5-0.6 # VSS
1 # COD REMOVED - 0.3-0.4 # VSS

YIELD COEFFICIENT - Y
- # VSS PRODUCED/# BOD REMOVED
MLVSS - 0.7 X MLSS

SLUDGE DECAY

MLVSS AERATED WITHOUT FOOD WILL

DECAY (REDUCE) BY ABOUT 5% PER DAY

DECAY COEFFICIENT - K_D - 0.5/DAY

179.2/11.1.18

ESTIMATING SLUDGE PRODUCTION
NET YIELD

#VSS PRODUCED -

Y X #BOD REMOVED - K_D X #VSS UNDER AERATION

NET YIELD COEFFICIENT - Y_{NET}

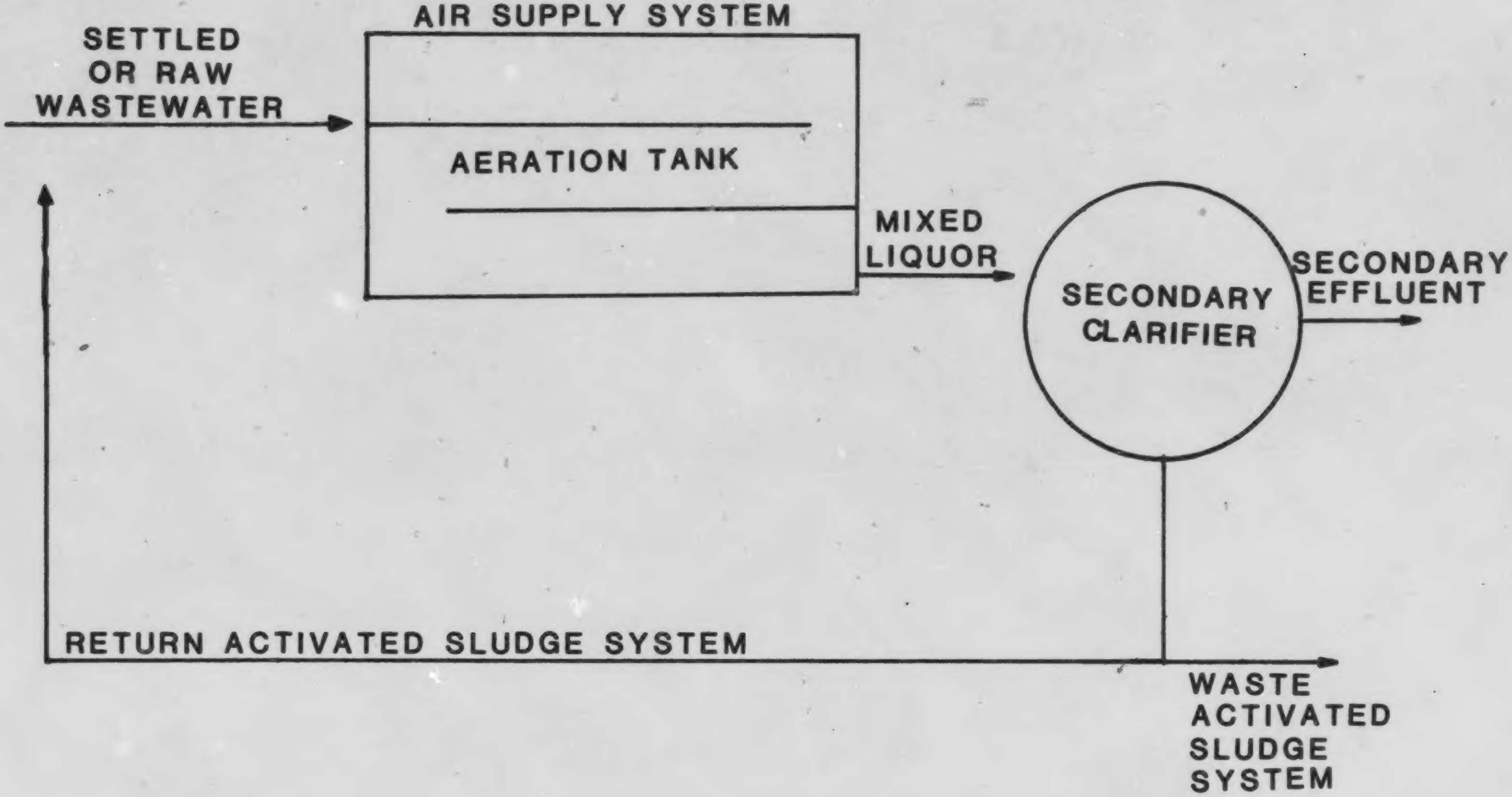
179.2/11.1.19

KEY POINTS

1. AEROBIC BIOLOGICAL REACTIONS
2. PRODUCE SETTLEABLE SOLIDS
3. REACTION RATES ARE A FUNCTION OF
    - A. TEMPERATURE
    - B. CONCENTRATION OF MLSS OR MLVSS
    - C. CONCENTRATION OF FOOD (BOD)
    - D. TYPES OF ORGANISMS IN SLUDGE
    - E. KINDS OF FOOD
    - F. AVAILABLE NUTRIENTS (N,P,F_E)
    - G. MIXING
    - H. TOXIC OR INHIBITORY SUBSTANCES

179.2/11.1.20

ACTIVATED SLUDGE SYSTEM


AIR SUPPLY SYSTEM
SETTLED OR RAW WASTEWATER
AERATION TANK
MIXED LIQUOR
SECONDARY CLARIFIER
SECONDARY EFFLUENT
RETURN ACTIVATED SLUDGE SYSTEM
WASTE ACTIVATED SLUDGE SYSTEM

179.2/11.2.2

ACTIVATED SLUDGE
PROCESS CONTROL PARAMETERS

A. FOOD TO MICROORGANISMRATIO (F/M)

B. MEAN CELL RESIDENCE TIME (MCRT)

C. DISSOLVED OXYGEN CONCENTRATION

D. AERATION DETENTION TIME

  1. HYDRAULIC DETENTION TIME

  2. SLUDGE AERATION TIME

E. SLUDGE SETTLING CHARACTERISTICS

F. OXYGEN UPTAKE OR RESPIRATION RATES (OUR) OR (RR)

DISSOLVED OXYGEN CONTROL

1. MAINTAIN 2.0 MG/L
2. D.O. THROUGHOUT AERATION TANK
3. AVOID SEPTIC CONDITIONS IN FINAL CLARIFIER
4. ADEQUATE MIXING

179 2/11.2.4

SOLIDS IN AERATION OR REAERATION TANK

# SOLIDS - VOL. OF TANK x SOLIDS CONC. x 8.34
(MG) (MG/L)

179.2/11.2.5

SOLIDS IN FINAL CLARIFIER

$$\#\ \text{SOLIDS} - \underset{\text{(MG)}}{\text{VOL. OF CLARIFIER}} \times \underset{\text{(MG/L)}}{\text{AVG. SOLIDS CONC.}} \times \frac{\text{SLUDGE BLANKET THICKNESS (FT)}}{\text{AVG. DEPTH OF CLARIFIER (FT)}} \times 8.34$$

AVERAGE SOLIDS CONCENTRATION -

$$\frac{\text{MIXED LIQUOR CONC. + RETURN SLUDGE CONCENTRATION}}{2}$$

ACTIVATED SLUDGE PROCESS CONTROL
EFFECT OF AERATION DETENTION TIME

DECREASE
- LESS STABLE SLUDGE
- SLOWER SETTLING RATE
- CONCENTRATES SLOWER

INCREASE
- MORE STABLE SLUDGE
- FASTER SETTLING RATE
- CONCENTRATES FASTER

ACTIVATED SLUDGE PROCESS CONTROL
EFFECT OF SLUDGE AERATION TIME

DECREASE

- LESS STABLE SLUDGE
- SLOWER SETTLING RATE
- CONCENTRATES SLOWER

INCREASE

- MORE STABLE SLUDGE
- FASTER SETTLING RATE
- CONCENTRATES FASTER

FOOD TO MICROORGANISM RATIO
(F/M)

$$F/M = \frac{\#\ \text{BOD}_5\ \text{APPLIED PER DAY}}{\#\ \text{SOLIDS INVENTORY}}$$

179.2/11.2.10

GOULD SLUDGE AGE
(GSA)

$$\text{GSA} - \frac{\text{\# SOLIDS INVENTORY}}{\text{\# PRIMARY EFFLUENT SUSPENDED SOLIDS / DAY}}$$

179.2/11.2.11

MEAN CELL RESIDENCE TIME (MCRT)

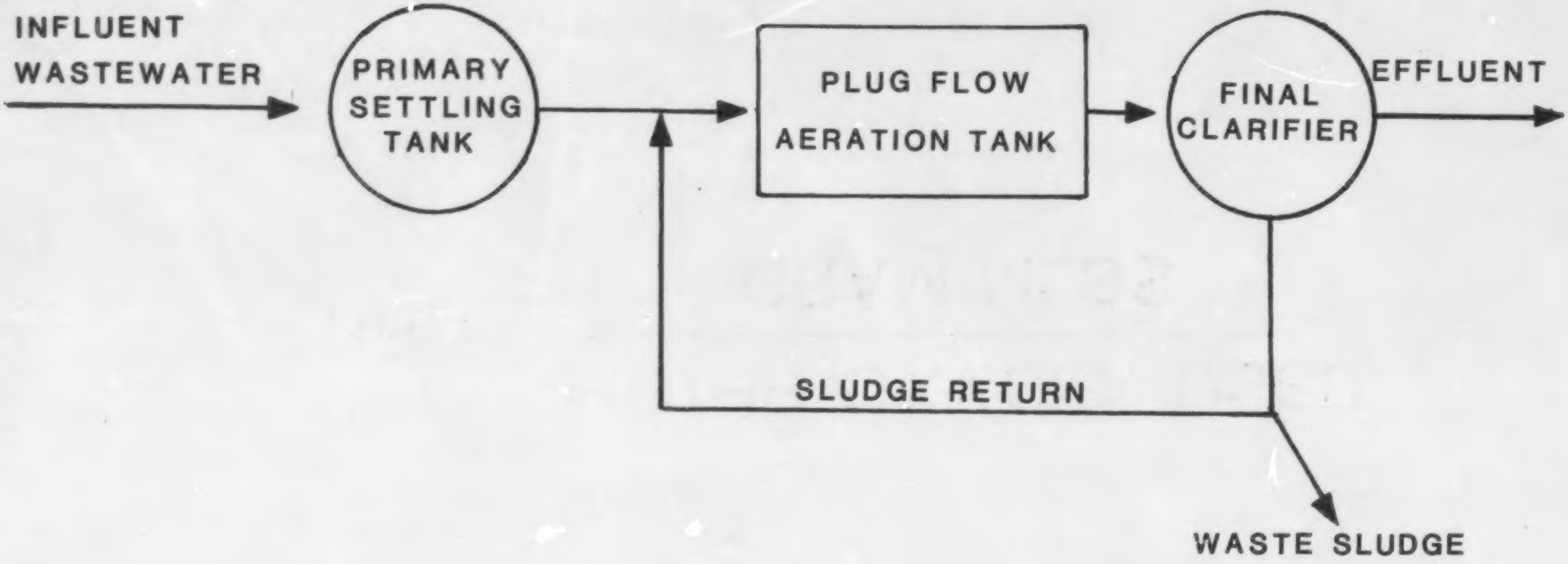
$$\text{MCRT} = \frac{\#\ \text{SOLIDS INVENTORY}}{\#\ \text{SOLIDS WASTED PER DAY}}$$

179.2/11.2.12

RESPIRATION RATE (RR)

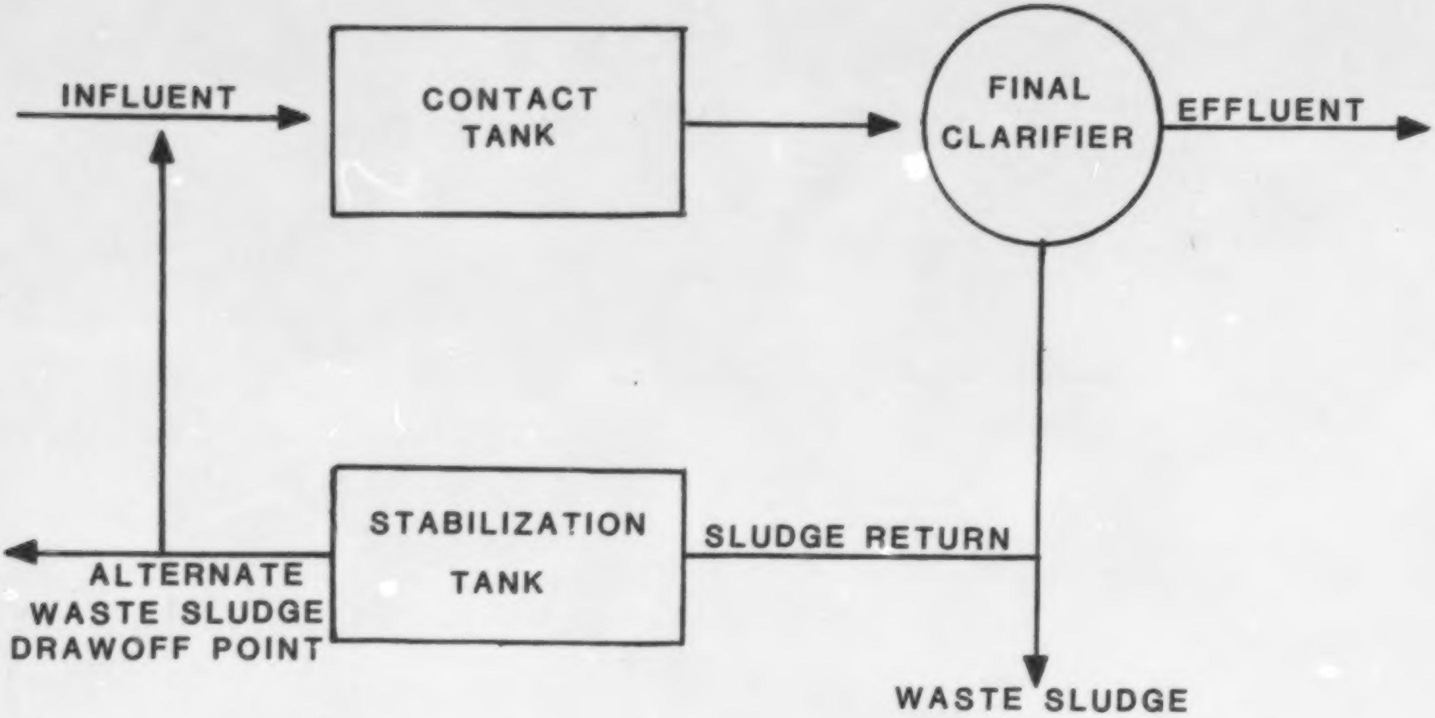
$$\text{RR} - \frac{\text{MG/HR OXYGEN USED}}{\text{GRAM MLSS}}$$

179.2/11.2.13



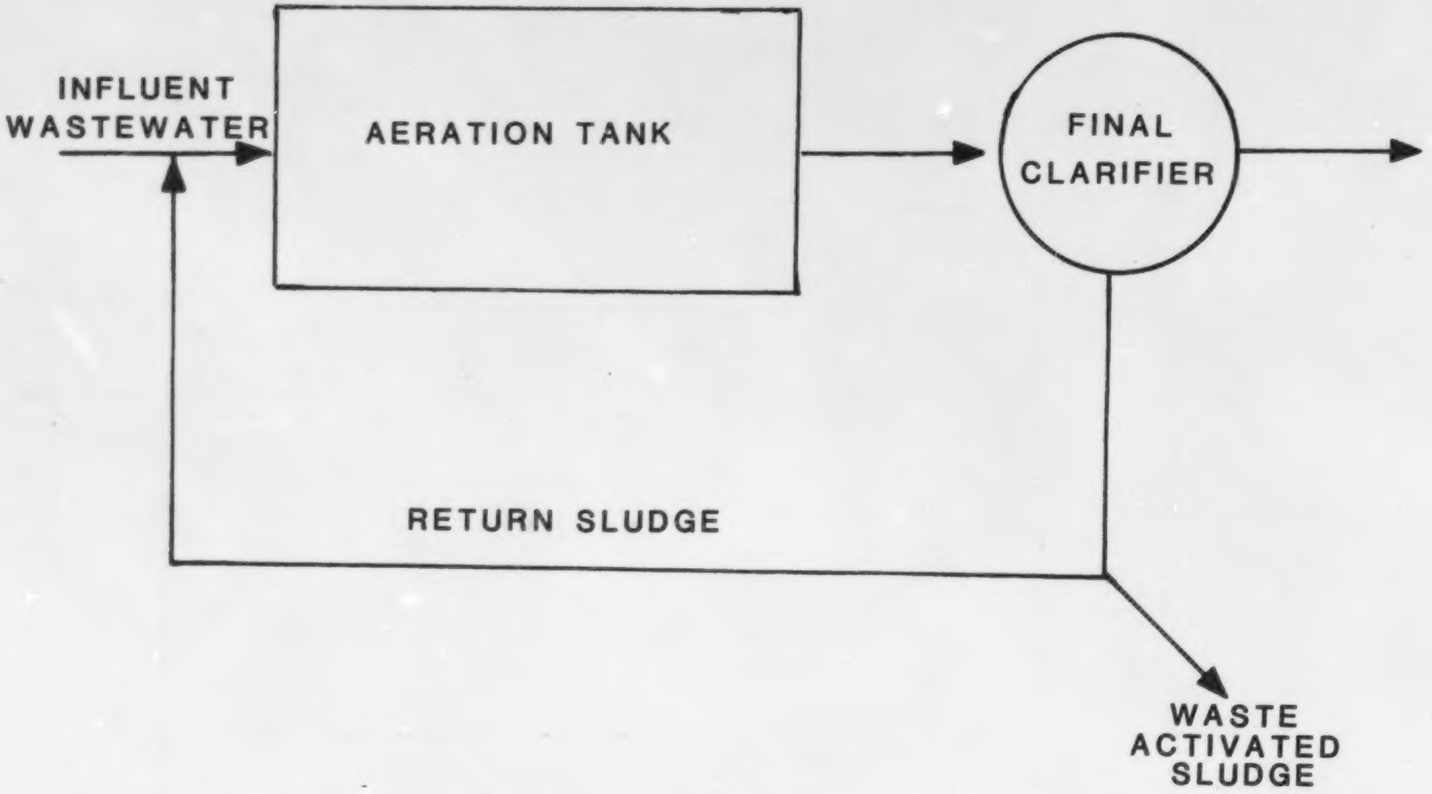
CONVENTIONAL ACTIVATED SLUDGE PROCESS

179.2/11.3.2



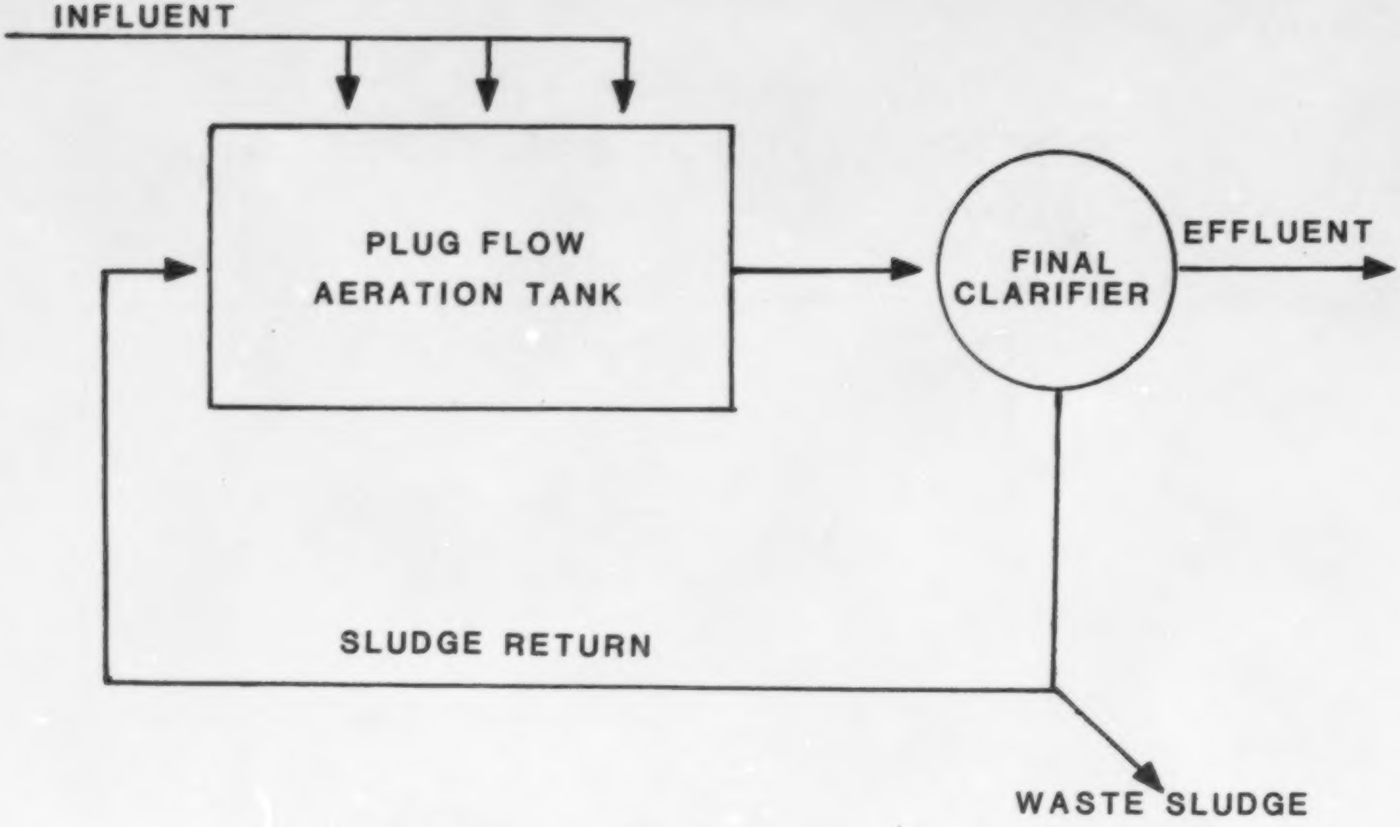
CONTACT STABILIZATION PROCESS

179.2/11.3.3

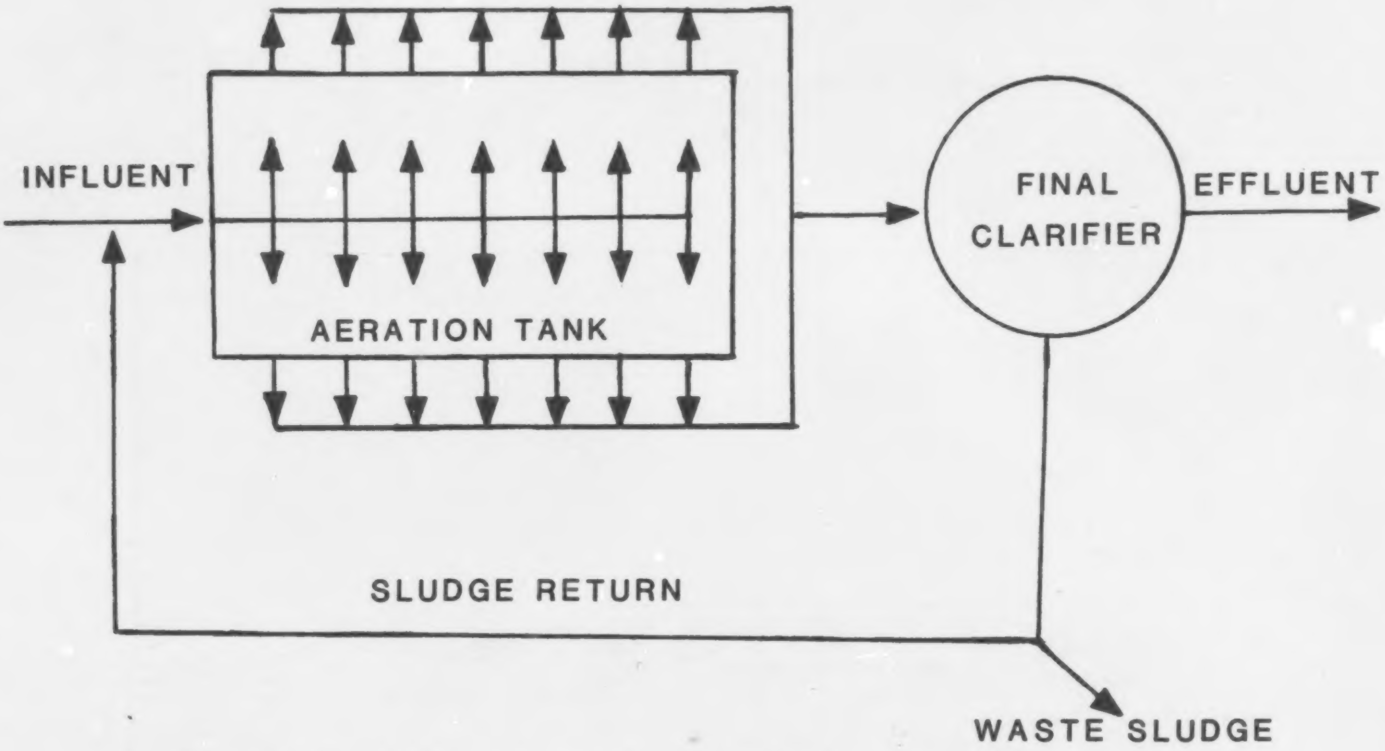


EXTENDED AERATION PROCESS

179.2/11.3.4



STEP FEED ACTIVATED SLUDGE PROCESS



COMPLETE MIXING ACTIVATED SLUDGE

179.2/11.3.6

MICROORGANISMS IN ACTIVATED SLUDGE

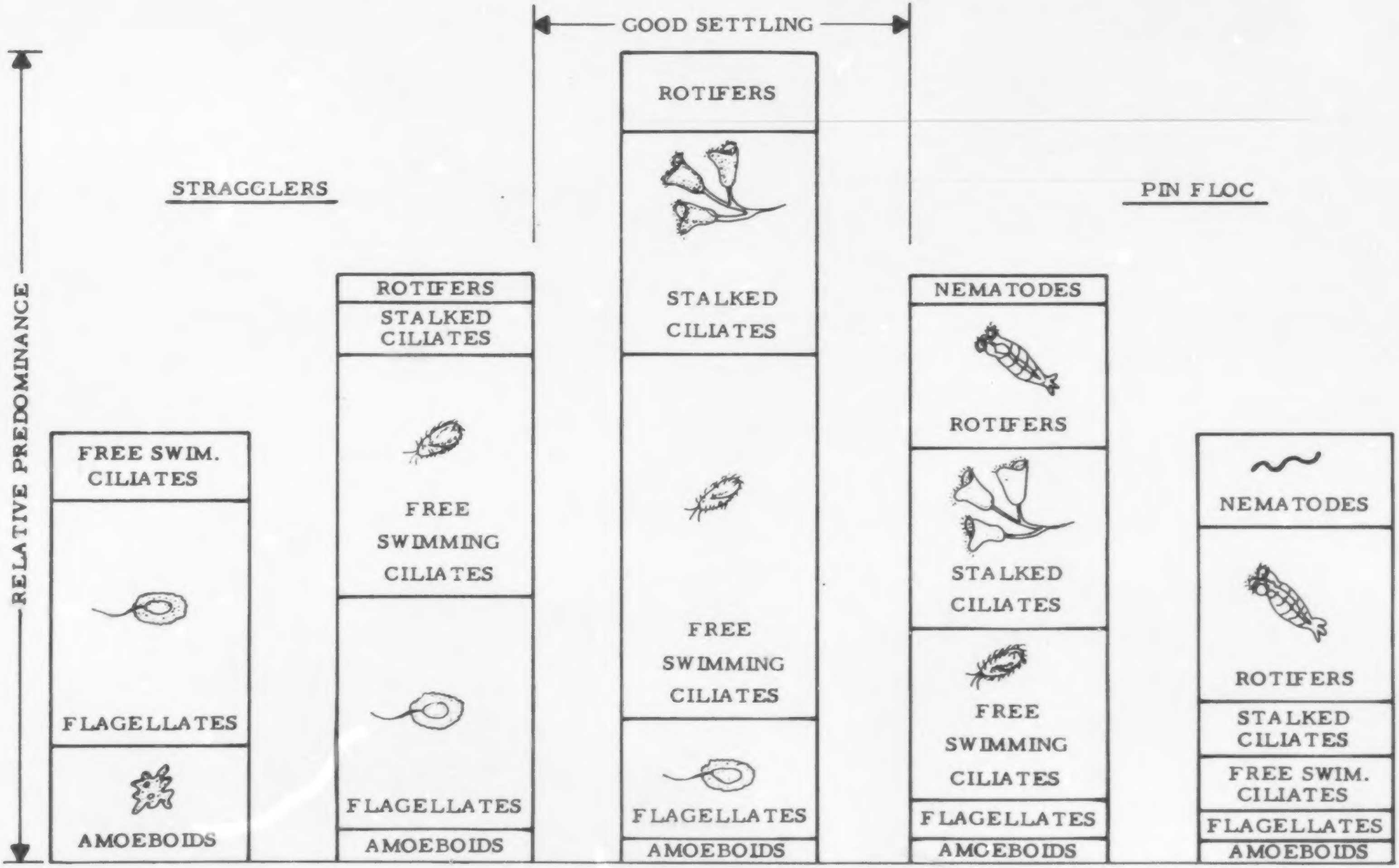
- BACTERIA
- AMOEBOIDS
- FLAGELLATES
- CILIATES
  - FREE SWIMMING CILIATES
  - STALKED CILIATES
- ROTIFERS AND OTHER "SMALL ANIMALS"
- FILAMENTS
- WORMS

SIGNIFICANCE OF MICROORGANISMS IN ACTIVATED SLUDGE

SLUDGE CONDITION	PROTOZOAN POPULATION
SATISFACTORY SLUDGE BACTERIA FLOCCULATE ACCEPTABLE SETTLEABILITY	LARGE NUMBER OF FREE SWIMMING CILIATES SOME STALKED CILIATES FEW 1. FLAGELLATES 2. AMOEBOIDS
GOOD SLUDGE GOOD SETTLEABILITY EFFLUENT BOD LOW	LARGE NUMBER OF STALKED CILIATES SOME FREE SWIMMING CILIATES FEW ROTIFERS VERY FEW FLAGELLATES

SIGNIFICANCE OF MICROORGANISMS IN ACTIVATED SLUDGE

SLUDGE CONDITION	PROTOZOAN POPULATION
BAD SLUDGE BACTERIAL DISPERSAL NO FLOCCULATION	LARGE NUMBER OF 1. FLAGELLATES 2. AMOEBOIDS RELATIVELY FEW CILIATES
UNSATISFACTORY SLUDGE BACTERIAL DISPERSAL SOME FLOCCULATION	PRESENT 1. FLAGELLATES 2. AMOEBOIDS SOME CILIATES 1. FREE SWIMMING 2. STALKED



RELATIVE NUMBER OF MICROORGANISMS VS. SLUDGE QUALITY

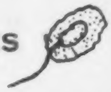
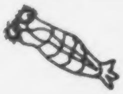
179.2/11.4.13

WORKSHEET FOR
MICROSCOPIC EXAMINATION OF
ACTIVATED SLUDGE

DATE: ____________________ TIME: ________ AM PM

BY: ____________________ TEMP: ________ °C

SAMPLE LOCATION: ____

MICROORGANISM GROUP	SLIDE NO. 1	SLIDE NO. 2	SLIDE NO. 3	TOTAL
AMOEBOIDS				
FLAGELLATES 				
FREE SWIMMING CILIATES				
STALKED CILIATES				
ROTIFERS 				
WORMS				

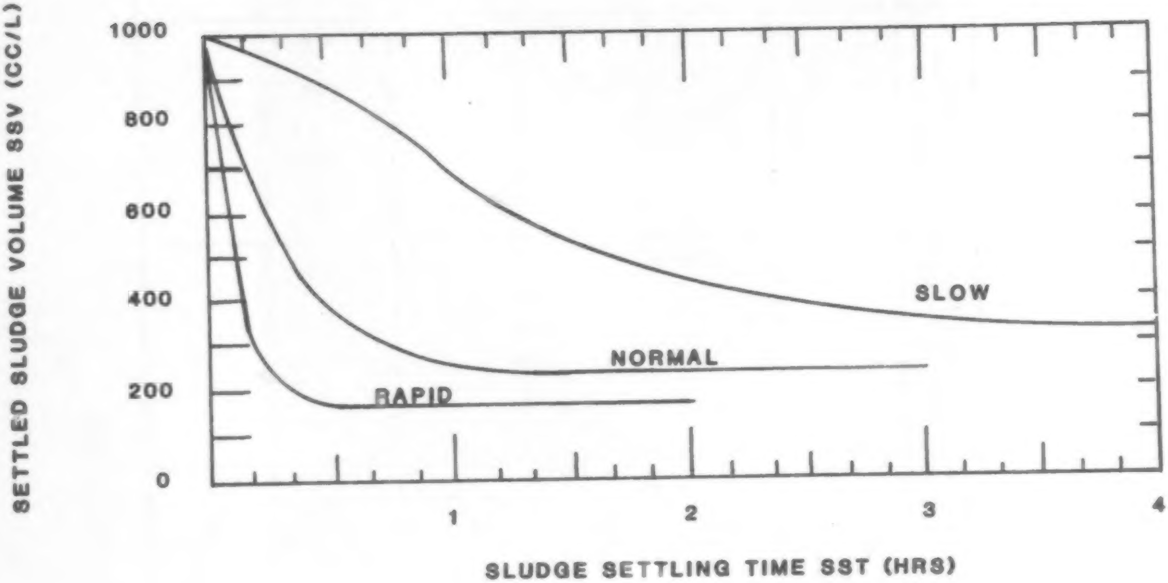
RELATIVE PREDOMINANCE:

1. ____________________

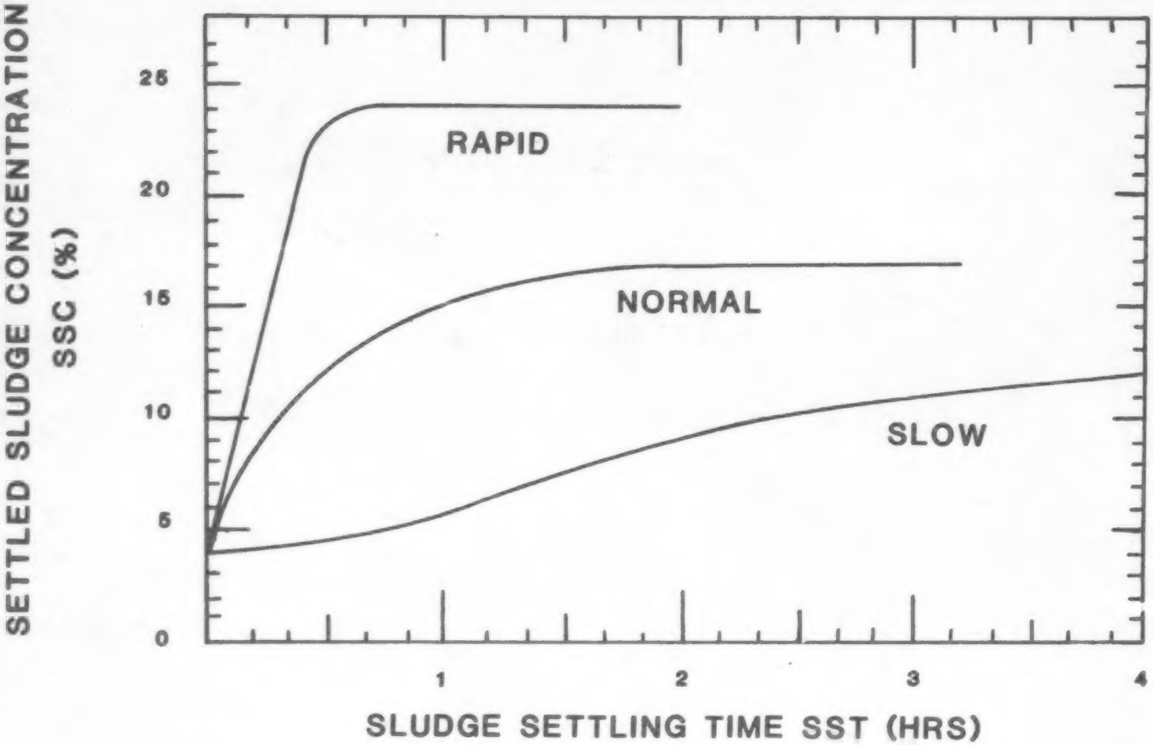
2. ____________________

3. ____________________

179.2/11.4.21


SETTLED SLUDGE VOLUME SSV (CC/L)
1000
800
600
400
200
0
SLOW
NORMAL
RAPID
1
2
3
4
SLUDGE SETTLING TIME SST (HRS)

179.2/11



$$SSC_T - \frac{ATC \times 1000}{SSV_T}$$

179.2/11.

1621

APPARATUS

- SAMPLING BOTTLES
- GRADUATED CYLINDERS
- BOD BOTTLES AND ADAPTER
- MAGNETIC STIRRER
- TIMER
- D.O. ANALYZER

179.2/11.6.2

CALIBRATE D.O. ANALYZER

179.2/11.6.4

OBSERVE AND RECORD

⊕ INITIAL TEMPERATURE

⊕ INITIAL D.O.

⊕ D.O. EVERY MINUTE

170.2/11.6.12

SIGNIFICANCE OF AERATION BASIN MIXED LIQUOR RESPIRATION RATE

- MONITORS STABILITY OF MIXED LIQUOR EFFLUENT SOLIDS
- CORRELATES WITH
    - SLUDGE SETTLEABILITY
    - BOD REMOVAL
    - ORGANIC LOADING
    - DETENTION TIME
    - SOLIDS INVENTORY

179.2/11.6.24

SE OF AERATION BASIN MIXED LIQUOR RESPIRATION RATE DATA

- ⊕ ADJUST RETURN SLUDGE RATE
- ⊕ ADJUST WASTING RATES
- ⊕ RESPOND TO AERATION BASIN DETENTION TIME CHANGES
- ⊕ RESPOND TO ORGANIC LOADING CHANGES
- ⊕ DETERMINE REAERATION REQUIREMENTS

179.2/11.6.25

AERATION BASIN
EFFLUENT RESPIRATION RATE

NORMAL RANGE – 12–20 MG/HR/GM

- ⊕ GOOD BOD REMOVAL
- ⊕ SETTLEABILITY
- ⊕ CLARIFICATION
- ⊕ SLUDGE CONCENTRATION

179.2/11.6.26

RATION BASIN EFFLUENT RESPIRATION RATE

HIGH- GREATER THAN 20 MG/HR/GM

SLUDGE IS: UNDER STABILIZED

SLOW SETTLING

CONCENTRATES POORLY

POSSIBLE CAUSES HIGH F/M

LOW SOLIDS INVENTORY (SHORT MCRT)

SHORT AERATION DETENTION TIME

INADEQUATE SOLIDS AERATION TIME

RESULTS- POSSIBLE HIGH EFFLUENT BOD & TSS

SLUDGE BLANKET RISES

POSSIBLE SOLIDS WASHOUT

DILUTE RETURN SLUDGE CONCENTRATION

POSSIBLE SEPTIC CLARIFIER

179.2/11.6.27

AERATION BASIN EFFLUENT RESPIRATION RATE

LOW- LESS THAN 12 MG/HR/GM

SLUDGE IS:

- OVER STABILIZED
- FAST SETTLING
- CONCENTRATES RAPIDLY

POSSIBLE CAUSES:

- LOW F/M
- HIGH SOLIDS INVENTORY (LONG MCRT)
- LONG AERATION DETENTION TIME
- TOXIC LOAD

POSSIBLE RESULTS:

- POSSIBLE HIGH EFFLUENT TSS
- SLUDGE BLANKET FALLS
- POOR CLARIFICATION
- CONCENTRATED RETURN SLUDGE
- POSSIBLE NITRIFICATION/DENITRIFICATION
- PIN FLOC OR ASHING

1629

ROUTINE PROCESS CONTROL USING RESPIRATION RATE DATA

- OPTIMIZE SYSTEM
- DETERMINE OPTIMUM RR OPERATING RANGE
- MAINTAIN RR TREND CHARTS
- RESPOND TO TREND CHARTS
- MAKE ONLY ONE CHANGE AT A TIME

179.2/11.6.29

CONTROL RESPONSES TO MIXED LIQUOR RESPIRATION RATE TRENDS

CONDITION: NORMAL OR SLOWLY SETTLING SLUDGE

RR INCREASING

- DECREASE RETURN RATE
- DECREASE WASTE RATE
- INCREASE SLUDGE AERATION TIME

RR DECREASING:

- INCREASE RETURN RATE
- INCREASE WASTE RATE
- DECREASE SLUDGE AERATION TIME

179.2/11.6.3

CONTROL RESPONSES TO MIXED LIQUOR RESPIRATION RATE TRENDS

CONDITIONS: FAST SETTLING SLUDGE
FINAL CLARIFIER SLUDGE BLANKET

RR INCREASING

- INCREASE RETURN RATE
- DECREASE WASTE RATE
- INCREASE SLUDGE AERATION TIME

RR DECREASING

- DECREASE RETURN RATE
- INCREASE WASTE RATE
- DECREASE SLUDGE AERATION TIME

178.2/11.6.31

CORRECTING MAJOR PROCESS IMBALANCE

- EVALUATE DESIGN & PAST OPERATING DATA
- CHARACTERIZE INFLUENT WASTE
- DETERMINE PROCESS CONDITION
  - F/M
  - MCRT
  - SLUDGE SETTLEABILITY
  - RESPIRATION RATES
  - DETENTION TIMES
- DETERMINE CAUSE OF PROBLEM
- RECOMMEND CORRECTIVE ACTION

UNFED SLUDGE RESPIRATION RATE

AMPLE: RETURN SLUDGE & FINAL EFFLUENT

AMPLE PROPORTIONS:

$$\frac{\text{VOL. RETURN SLUDGE}}{\text{VOL. FINAL EFFLUENT}} = \frac{\text{RETURNED SLUDGE FLOW RATE}}{\text{INFLUENT FLOW RATE}}$$

EASURES:

CONDITION OF SLUDGE AFTER

AERATION AND SETTLING

179.2/11.6.33

1634

FED SLUDGE RESPIRATION RATE

SAMPLE: RETURN SLUDGE & AERATION BASIN INFLUENT

SAMPLE PROPORTIONS:

$$\frac{\text{VOL. RETURN SLUDGE}}{\text{VOL. INFLUENT}} = \frac{\text{RETURNED SLUDGE FLOW RATE}}{\text{INFLUENT FLOW RATE}}$$

MEASURES:

ORGANIC LOAD APPLIED TO AERATION BASIN

179.2/11.6.34

LOAD FACTOR

$$\text{LOAD FACTOR} - \frac{\text{FED SLUDGE RR}}{\text{UNFED SLUDGE RR}}$$

179.2/11.6.35

INTERPRETATION OF LOAD DATA

$LF < 1$	INHIBITORY OR TOXIC LOAD
$1 < LF < 2$	DILUTE OR STABLE LOAD
$2 < LF < 5$	ACCEPTABLE LOAD
$LF > 5$	POTENTIAL O_2 SUPPLY PROBLEM

179.2/11.6.36

STABILIZATION TIME TESTS INDICATE

- EVENTS IN PROGRESSION AFTER FEEDING
- POSSIBLE LAGS
- IRREGULAR PROGRESSION OR PHASES
- EXTENDED TIME REQUIRMENTS
- EXCESSIVE PEAK UPTAKE RATES

179.2/11.0.88

EFFLUENT OXYGEN UPTAKE

179.2/11.6.41

EFFLUENT QUALITY

THE BOD TEST IS A LONG TERM EFFLUENT QUALITY INDEX

△ D.O. (100% SAMPLE) AT 15 TO 30 MINUTE INTERVALS GIVES AN EFFLUENT QUALITY INDEX IN LESS THAN FOUR HOURS

179.2/11.6.42

SUMMARY

1612

179.2/11.6.43

RESPIRATION RATE

- CONCENTRATION (MLSS) INDEPENDENT

- UNITS MG O_2 /HR/GM

- OPTIMUM MLSS RR 12-20

179.2/11.8.44

ACTIVATED SLUDGE MIXED LIQUOR RESPIRATION RATE

EACH OPERATING TREATMENT FACILITY UNDER USUAL CONDITIONS WILL HAVE A PREFERRED RANGE OF RESPIRATION RATES WITHIN WHICH THAT PLANT WILL SHOW ITS BEST CONTINUING PERFORMANCE

179.2/11.6.

1645

ACTIVATED SLUDGE RESPIRATION RATES

INTERPRETATION

1) INCREASING MLSS RATES

DECREASING SLUDGE STABILITY NEEDS INCREASED OXIDATION PRESSURE TO PREVENT OVERLOADING (DECREASED SETTLEABILITY)

2) INCREASING FED SLUDGE RATES

MAY APPROACH LIMITING OXYGENATION CAPACITIES,DECREASE LOAD TO UNIT, DISTRIBUTE LOAD TO UNIT, CONTACT MODIFICATION OR CHEMICAL COAGULATION

179.2/11.6.48

ACTIVATED SLUDGE RESPIRATION RATE

INTERPRETATION

A DECREASE IN THE RESPIRATION RATE ON FED SLUDGE RELATIVE TO AN UNFED ENDOGENOUS RATE INDICATES TOXICITY OR UNFAVORABLE CONDITIONS, NEEDS TIME FOR REGROWTH

179.2/11.6.47

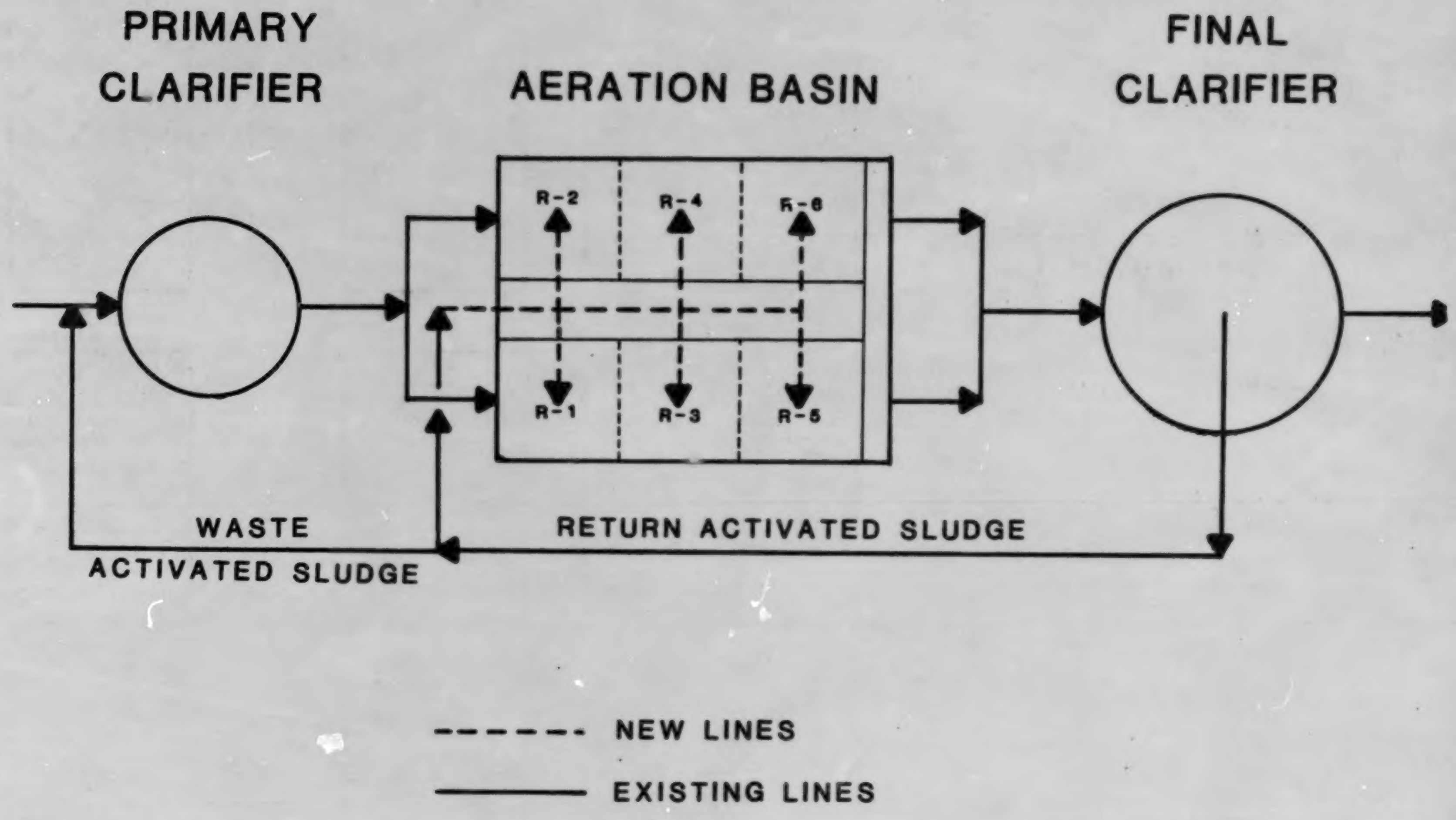
SLUDGE STABILIZATION

EFFLUENT QUALITY RELATIONSHIPS

UNDER OR OVER OXIDIZED SLUDGES–
LOWER EFFLUENT QUALITY

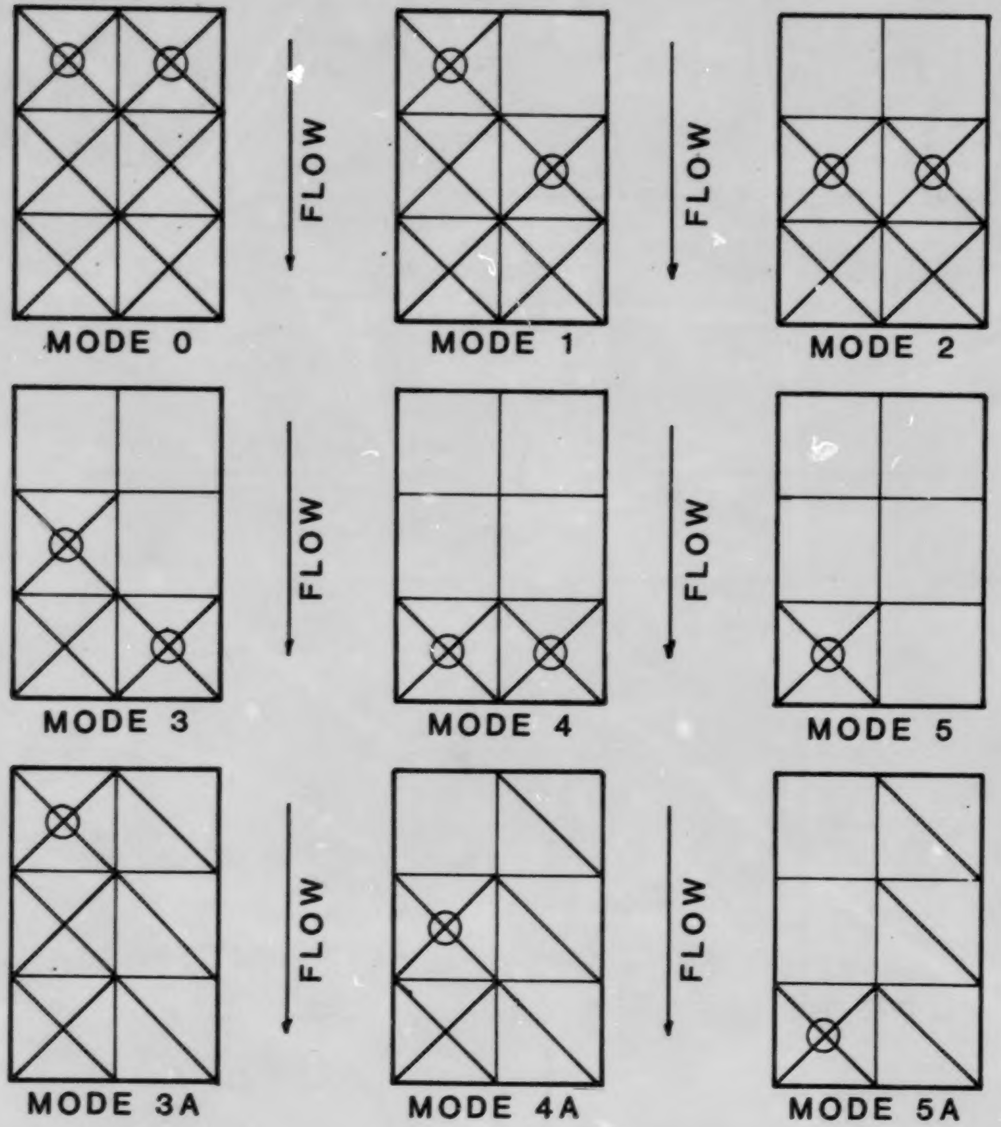
SOME INTERMEDIATE STABILIZATION RANGE–
BEST EFFLUENT QUALITY

RELATABLE TO RESPIRATION RATES



MODIFIED RETURN SLUDGE SYSTEM

OPERATING MODES

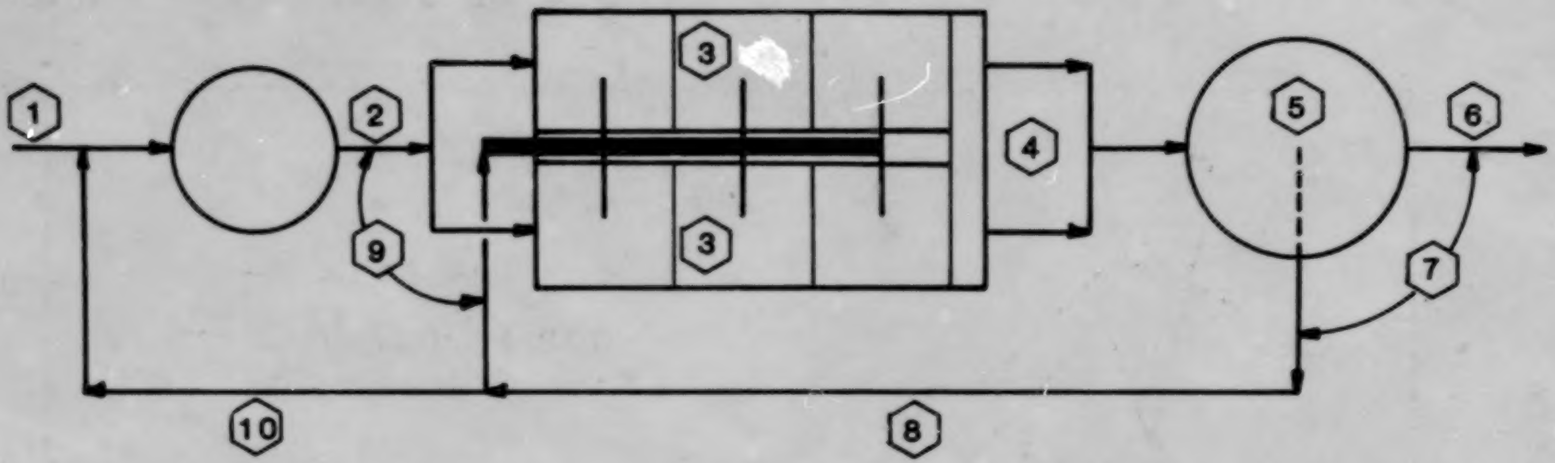


○ RAS DISCHARGE

☒ RAS + PRIMARY EFFLUENT

⧅ NO PRIMARY EFFLUENT

179.2/11.10.3

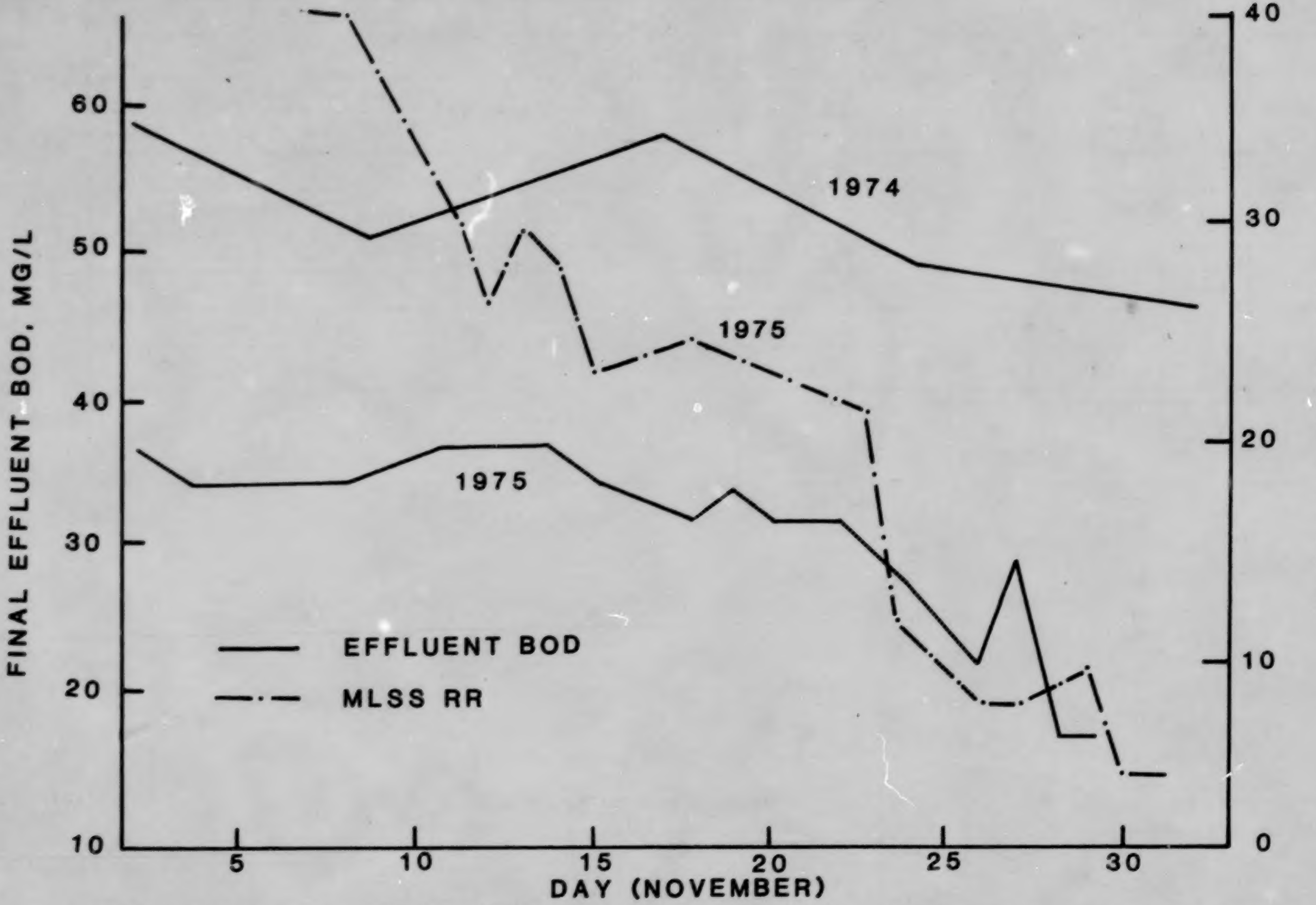


SAMPLE POINTS AND FREQUENCY

SAMPLE	FLOW	SOLIDS		BOD	% SET.	RR	DOB
		GRAV.	CENT.				
1 RAW WASTE	C	4/W		4/W			
2 PRIMARY EFFLUENT	C	4/W		4/W			
3 MIXED LIQUOR			2/D				
4 AERATION BASIN EFFLUENT		1/D	4/D		3/D	3/D	
5 FINAL CLARIFIER							2/D
6 FINAL EFFLUENT		4/W		4/W			
7 UNFED SLUDGE			3/D			3/D	
8 RETURN SLUDGE	C	1/D	4/D				
9 FED SLUDGE			3/D			3/D	
10 WASTE SLUDGE	C	1/D	3/D				

179.2/11.10.4

C = CONTINUOUS #/W = #/WEEK #/D = #/DAY

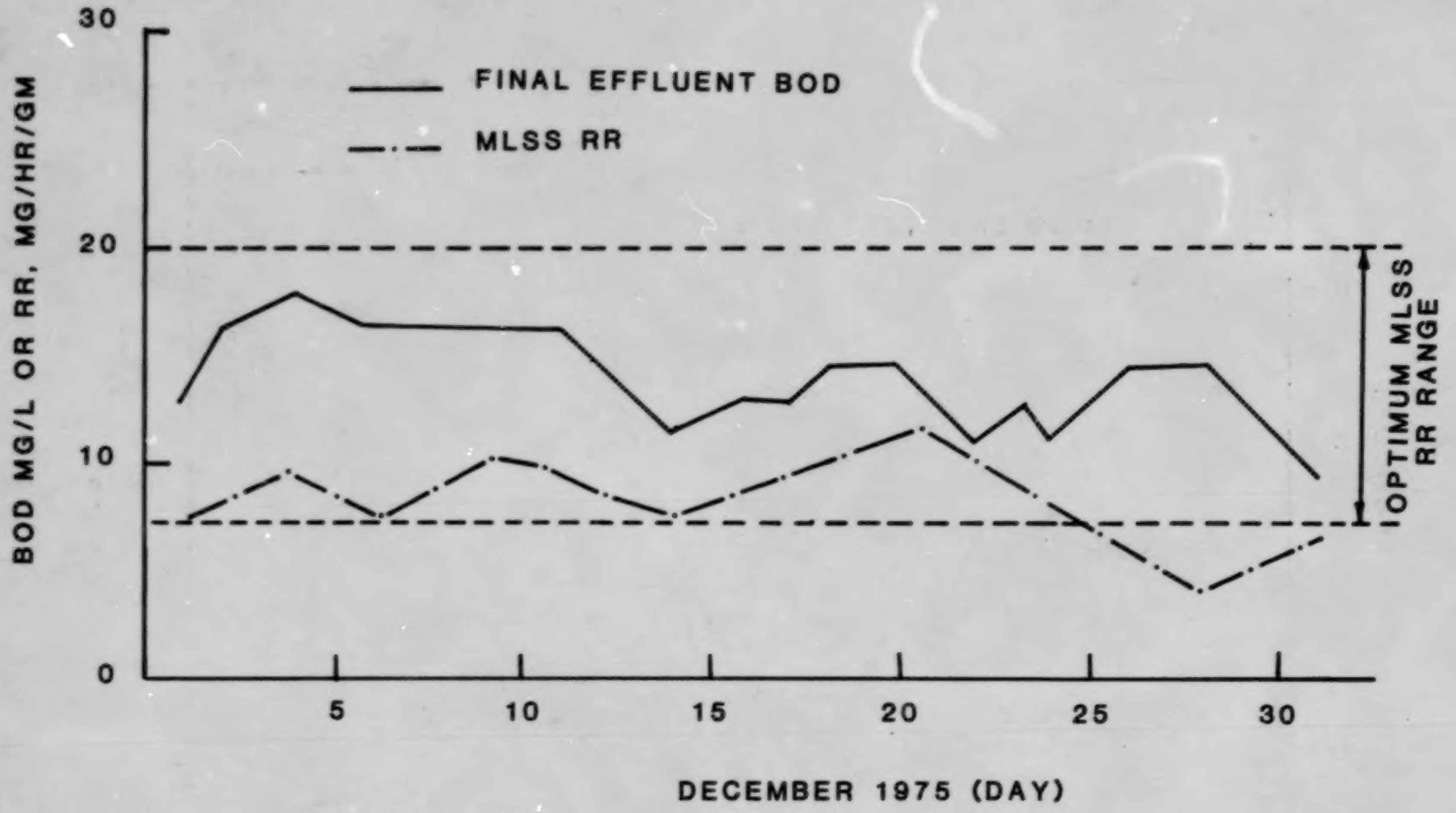


PULLMAN TREATMENT PLANT PERFORMANCE

179.2/11.10.5

1658

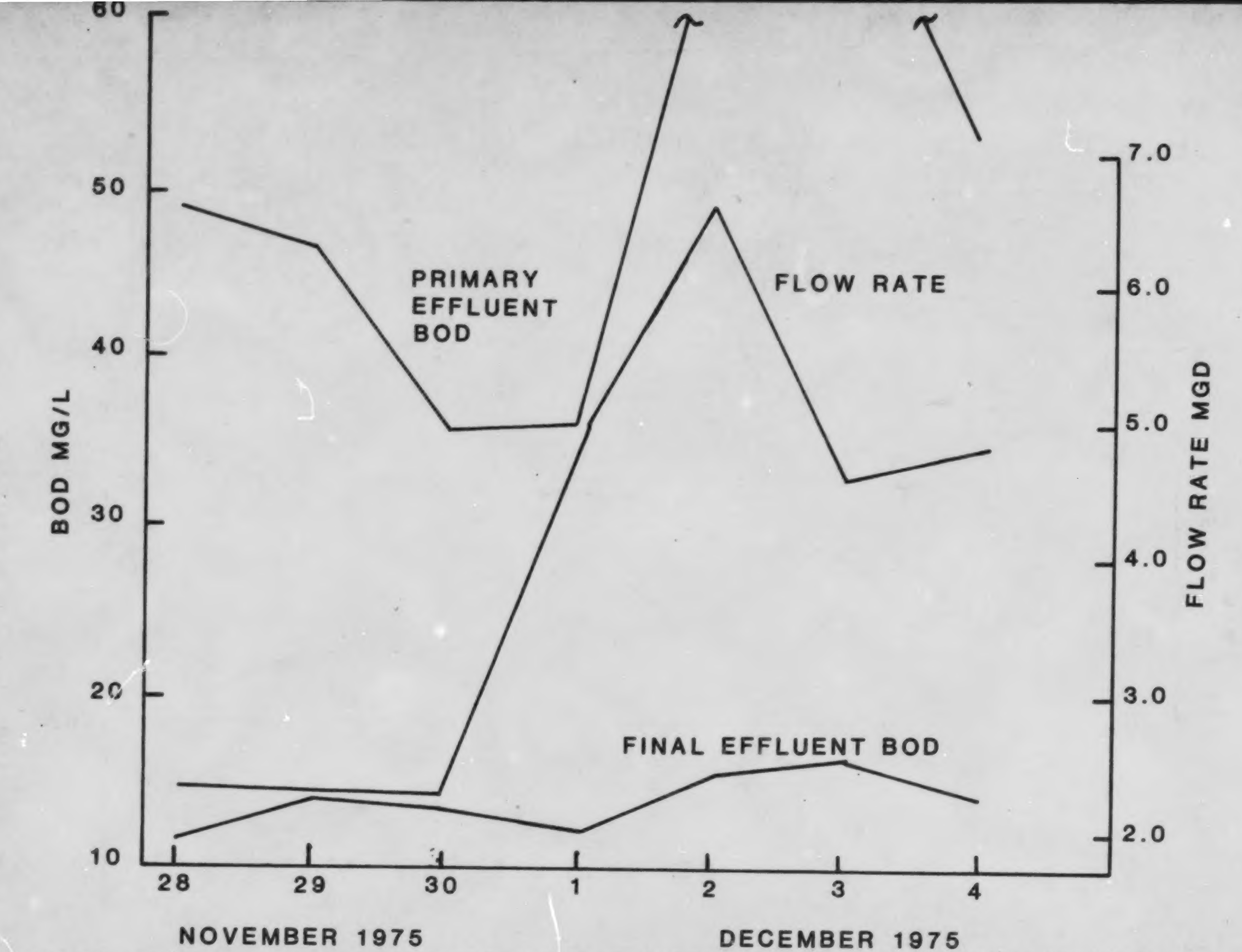
1657



PERFORMANCE OF PULLMAN TREATMENT PLANT USING MODIFIED RETURN SLUDGE SYSTEM AND RR CONTROL

1659

179.2/11.10.6



FINAL EFFLUENT RESPONSE TO INFLUENT LOAD CHANGES AT PULLMAN TREATMENT USING MODIFIED RETURN SLUDGE SYSTEM AND RR CONTROL

1661

179.2/11-10.7

1662

BULKING SLUDGE

SETTLES VERY SLOWLY AND DOES NOT COMPACT

SLUDGES HAVING SVI > 200 ARE USUALLY CLASSED AS BULKING SLUDGES.

NORMAL SLUDGE

FEW SHORT FILAMENTS

ORGANISMS PRESENT INCLUDE

- BACTERIA
- PROTOZOA
- FREE-SWIMMING CILIATES
- STALKED CILIATES
- NEMATODES
- ROTIFERS
- CRUSTACEANS
- INSECTS

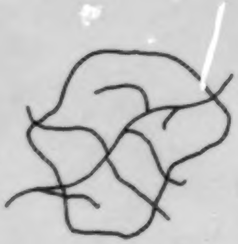
FLOCCULENT

PRODUCES CLEAR EFFLUENT WHICH CONTAINS FEW INDIVIDUAL BACTERIA OR OTHER PARTICLES

170.2/11.12.

EXAMPLES OF ACTIVATED SLUDGE FLOCS

NORMAL "NONBULKING"



I. FILAMENTOUS ORGANISMS AND ZOOGLEA IN BALANCE

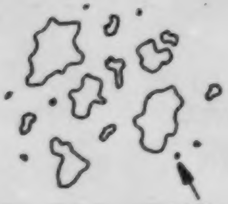
II. STRONG, LARGE FLOC

III. FILAMENTS DO NOT INTERFERE

IV. CLEAR SUPERNATANT

V. GOOD SETTLING CHARACTERISTICS AND LOW SVI

"PIN-POINT" OR DISPERSED



DISPERSED PARTICLE

I. NO FILAMENTOUS ORGANISMS

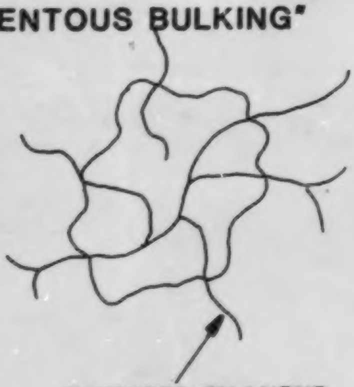
II. WEAK, SMALL FLOC

III. FILAMENTS DO NOT INTERFERE

IV. TURBID SUPERNATANT WITH HIGH TSS

V. SETTLES RAPIDLY AND HAS LOW SVI (DISPERSED GROWTH MAY NOT SETTLE)

"FILAMENTOUS BULKING"



EXTENDED FILAMENT

I. FILAMENTOUS ORGANISMS PREDOMINATE

II. STRONG ,LARGE FLOC

III. EXTENDED FILAMENTS INTERFERE WITH SETTLING AND COMPACTION

IV. CLEAR SUPERNATANT

V. SETTLES VERY SLOWLY (IF AT ALL) AND HAS HIGH SVI

179.2/11.12.6

1666

SLUDGE SETTLING PROBLEMS

1. FINAL CLARIFIER PHYSICAL PROBLEMS

2. LOW DENSITY
    - RISING SLUDGE
    - ANAEROBIC SLUDGE
    - OVER AERATED SLUDGE

3. POOR FLOC FORMATION
    - STRAGGLER FLOC
    - PIN FLOC
    - DEFLOCCULATION
    - DISPERSED GROWTH

4. POOR COMPACTION
    - FILAMENTOUS BULKING
    - ZOOGLEAL BULKING (NON FILAMENTOUS BULKING)

179.2/11.12.7

FINAL CLARIFIER PHYSICAL PROBLEMS

BILLOWING SLUDGE .

170.2/11.12.8

POSSIBLE CAUSES OF BILLOWING SLUDGE

1. HYDRAULIC OVERLOAD

2. POOR CLARIFIER DESIGN
   - A. SHORT CIRCUITING
   - B. INADEQUATE WEIR LENGTH
   - C. IMPROPER WEIR PLACEMENT
   - D. INADEQUATE CLARIFIER DEPTH
   - E. POOR COLLECTOR PLACEMENT

3. POOR CLARIFIER O&M
   - A. INADEQUATE SLUDGE PUMPING
   - B. PLUGGED INLETS AND OUTLETS
   - C. UNLEVEL WEIRS
     - IN ONE TANK
     - BETWEEN TANKS
   - D. PLUGGED COLLECTORS
   - E. MISSING FLIGHTS

4. SOLIDS OVERLOADING

1669

FINAL CLARIFIER SOLIDS REMOVAL MECHANISMS

*SOLIDS SETTLING

*BULK TRANSPORT

179.2/11.12.12

SOLIDS FLUX

FLUX – THE QUANTITY OF MATERIAL PASSING THROUGH A UNIT AREA IN A UNIT TIME

UNITS – POUNDS/SQUARE FOOT/HOUR

170.2/11.12.13

BULK TRANSPORT SOLIDS FLUX

DEFINITION:

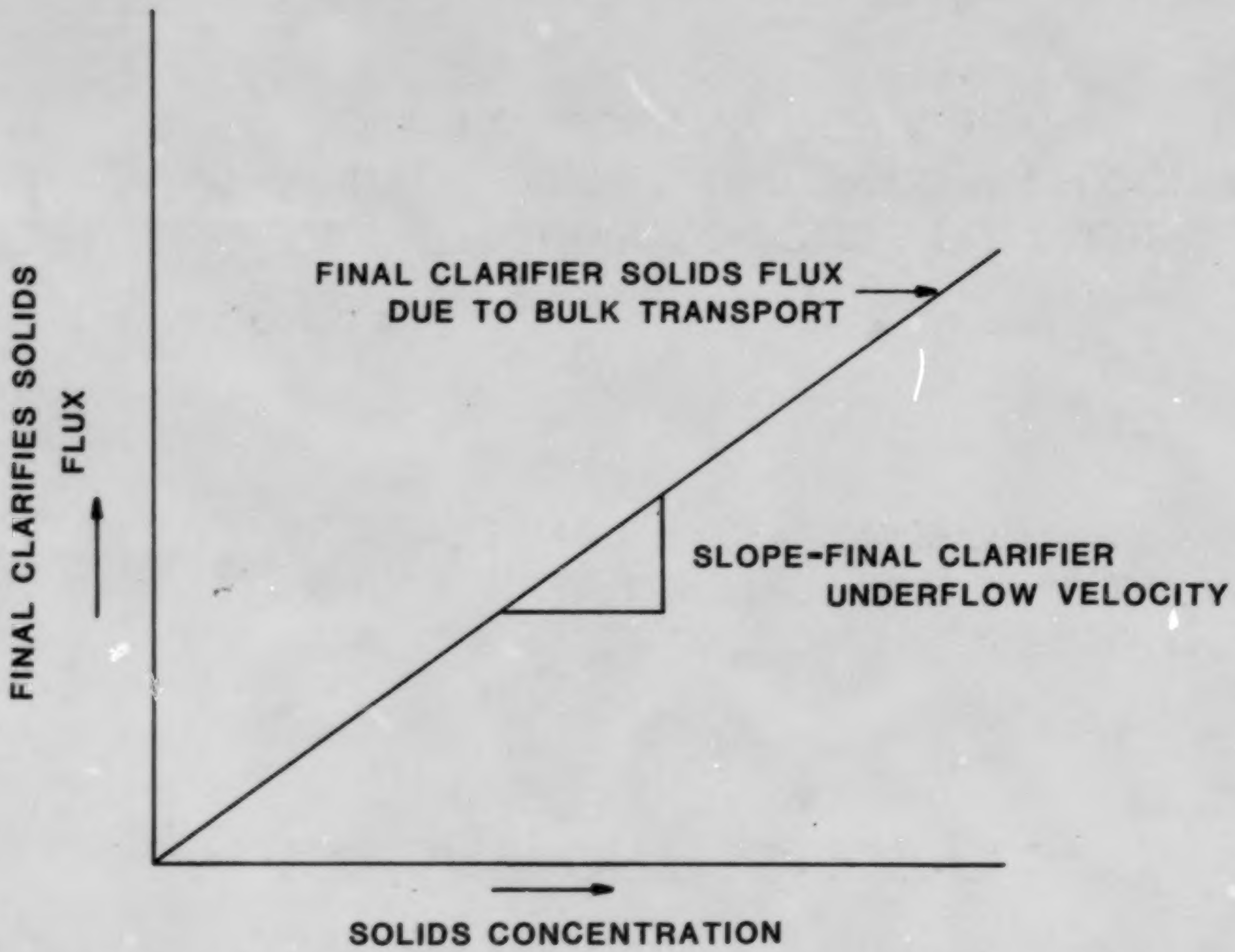
THE QUANTITY OF SOLIDS CARRIED THROUGH A UNIT AREA IN A UNIT TIME BY THE FINAL CLARIFIER HYDRAULIC UNDERFLOW

FORMULA:

BULK TRANSPORT SOLIDS FLUX (LBS /FT^2/HR)-
FINAL CLARIFIER UNDERFLOW VELOCITY (FT/HR)x
SOLIDS CONCENTRATION (LBS /FT^3)

179.2/11.12.14

FINAL CLARIFIER BULK TRANSPORT SOLIDS FLUX AS A FUNCTION OF SOLIDS CONCENTRATION



179.2/11.12.15

FINAL CLARIFIER SOLIDS SETTLING FLUX

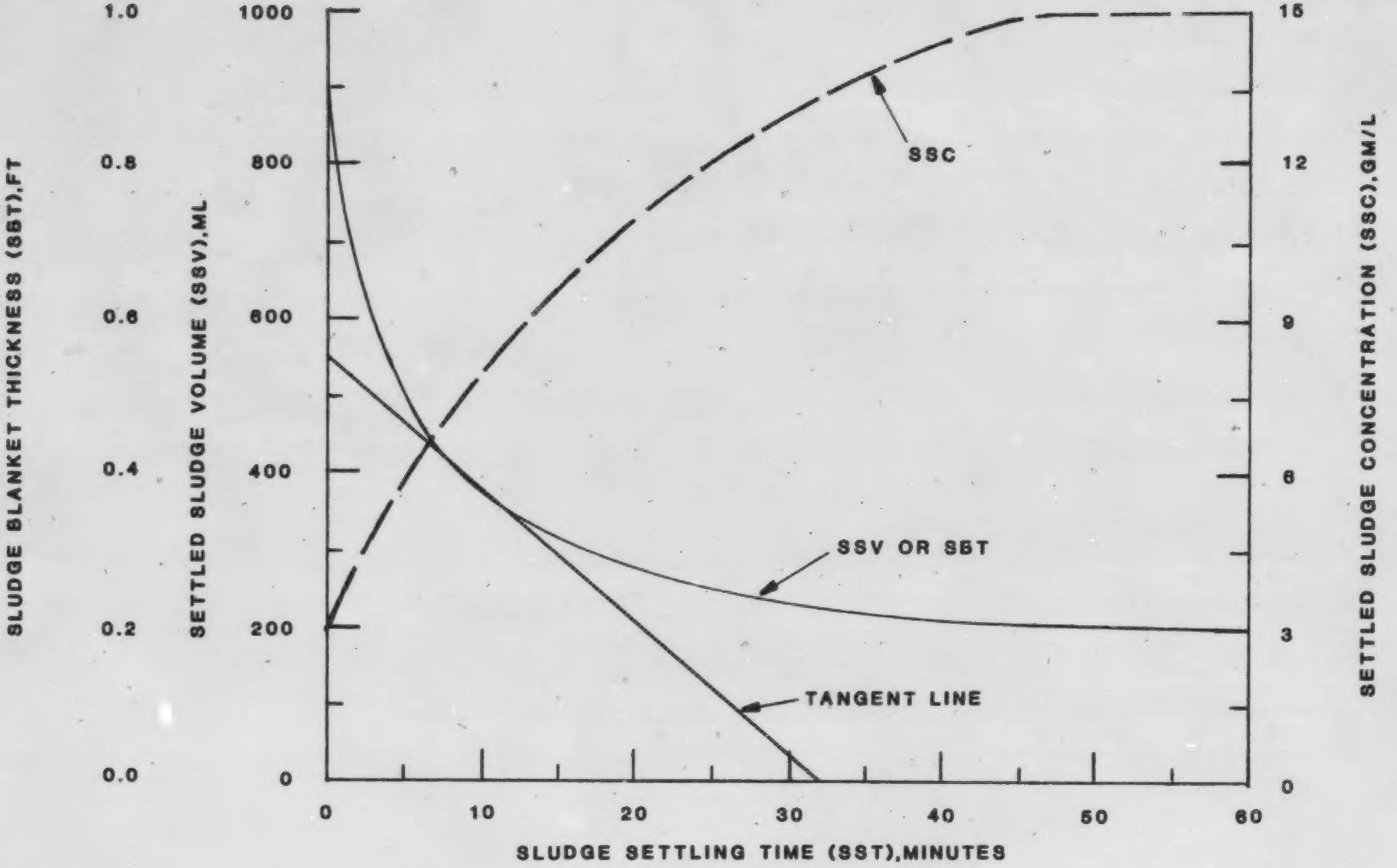
DEFINITION:

THE QUANTITY OF SOLIDS WHICH PASS THROUGH A UNIT AREA IN A UNIT TIME AS A RESULT OF GRAVITY SETTLING

FORMULA:

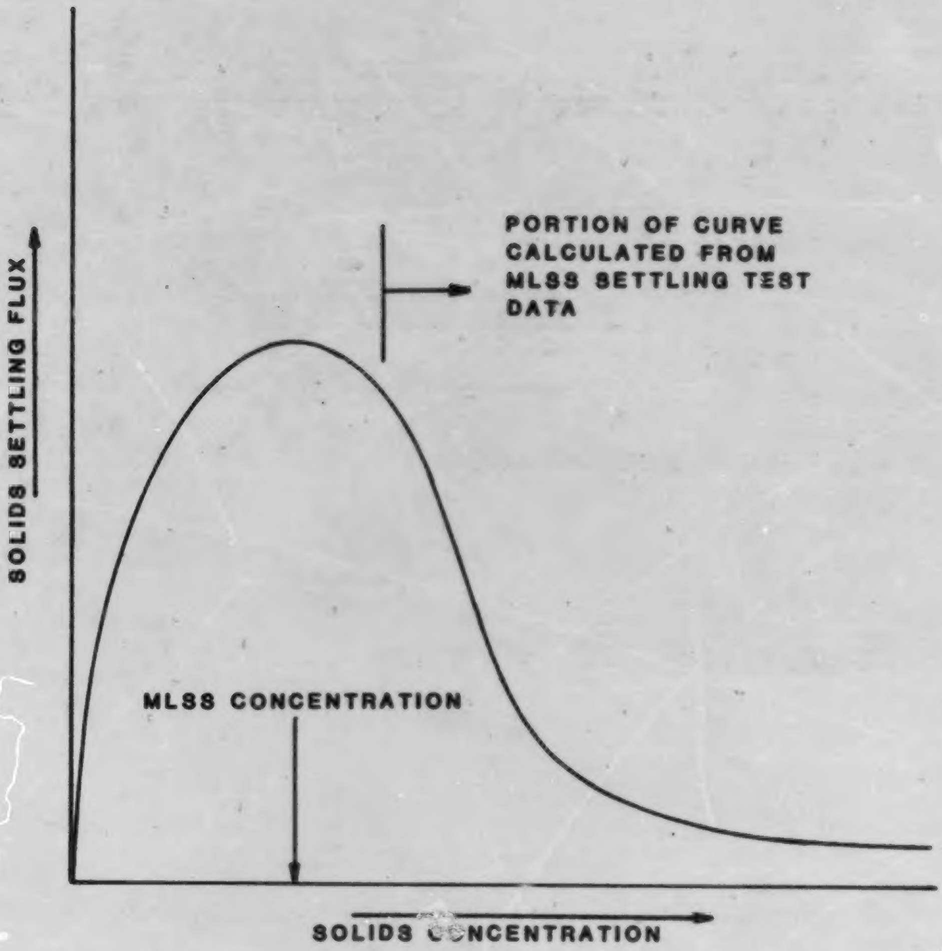
SOLIDS SETTLING FLUX ($LBS/FT^2/HR$) -
SOLIDS SETTLING VELOCITY (FT/HR) x
SOLIDS CONCENTRATION (LBS/FT^3)

179.2/11.12.16



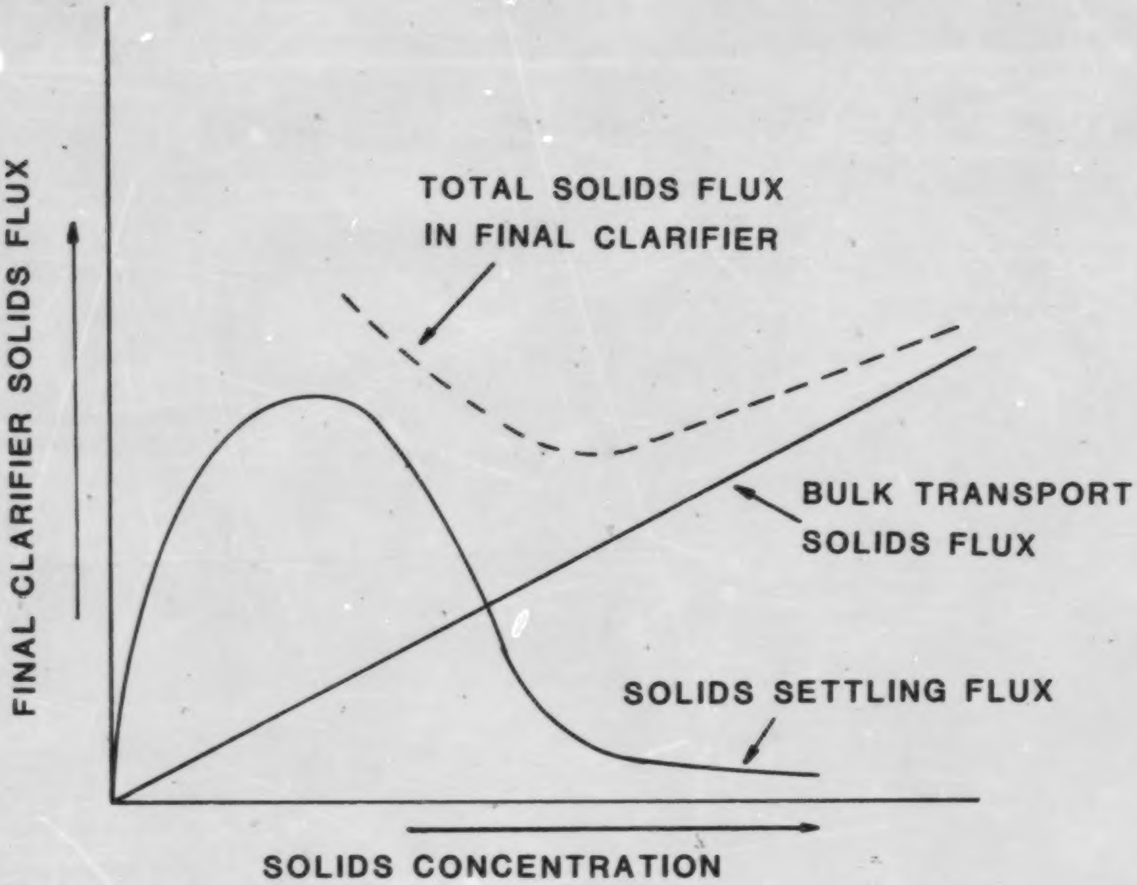
CALCULATING SOLIDS SETTLING VELOCITY FROM SOLIDS SETTLING TEST DATA

179.2/11.12.17



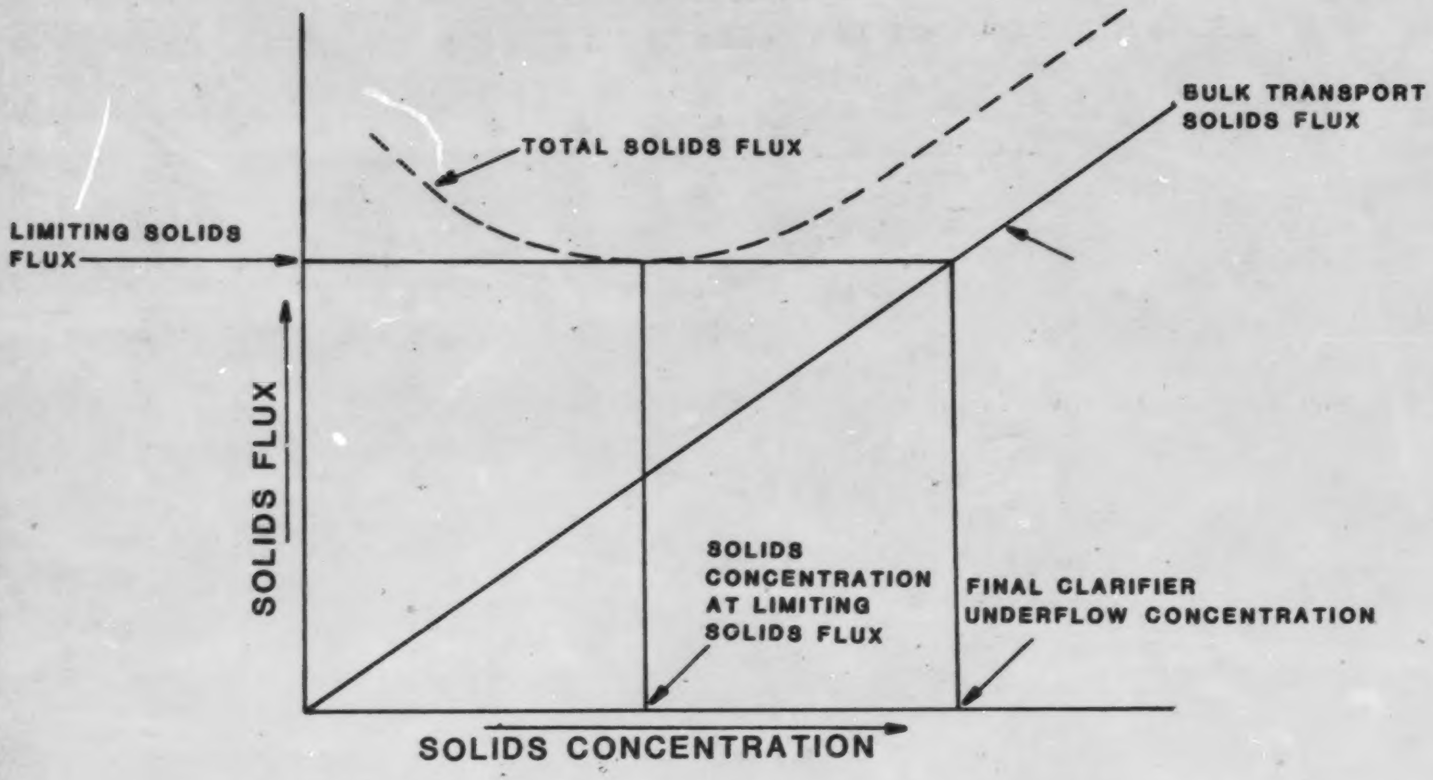
TYPICAL SOLIDS SETTLING FLUX CURVE

179.2/11.12.1



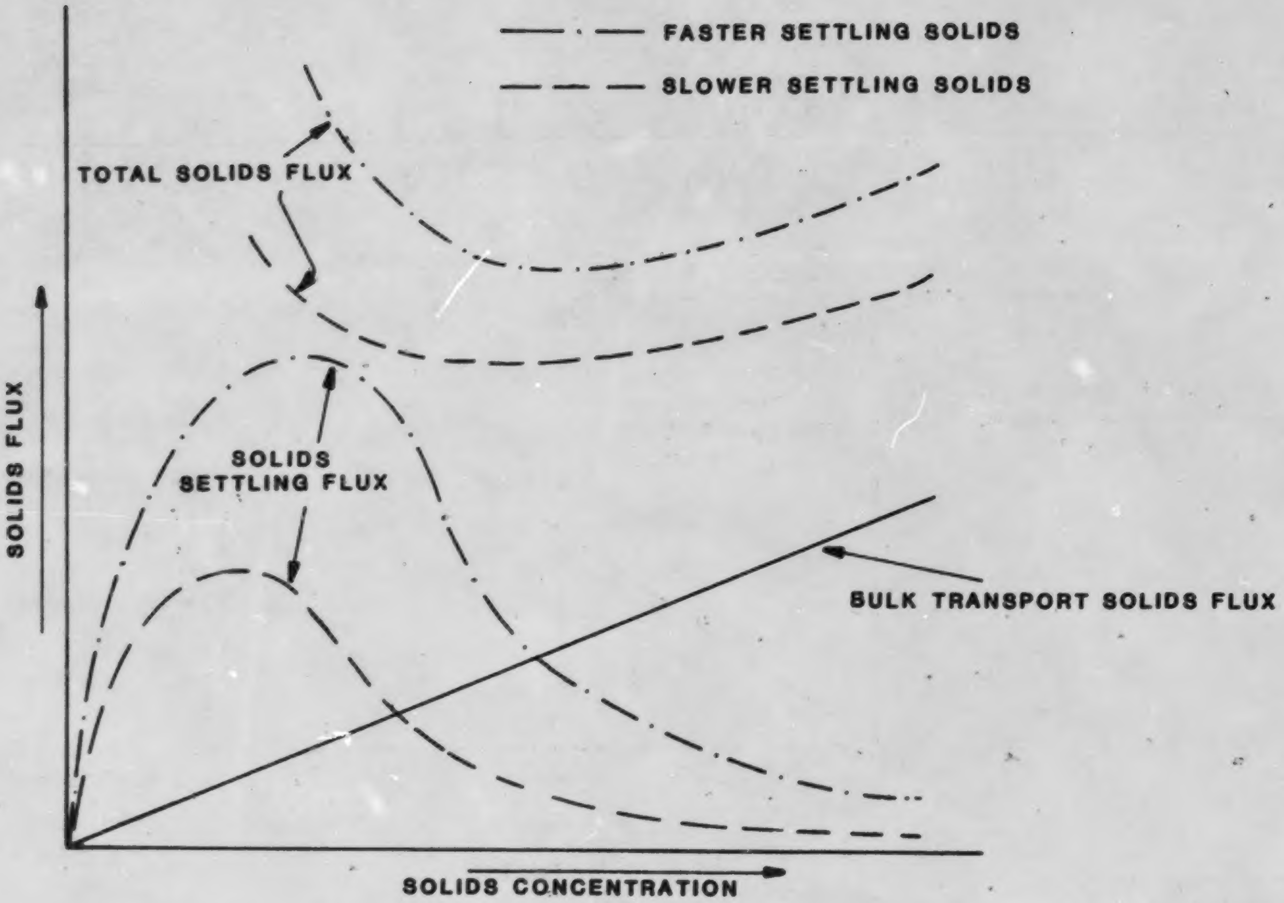
TYPICAL TOTAL FINAL CLARIFIER SOLIDS FLUX

170.2/11.12.16



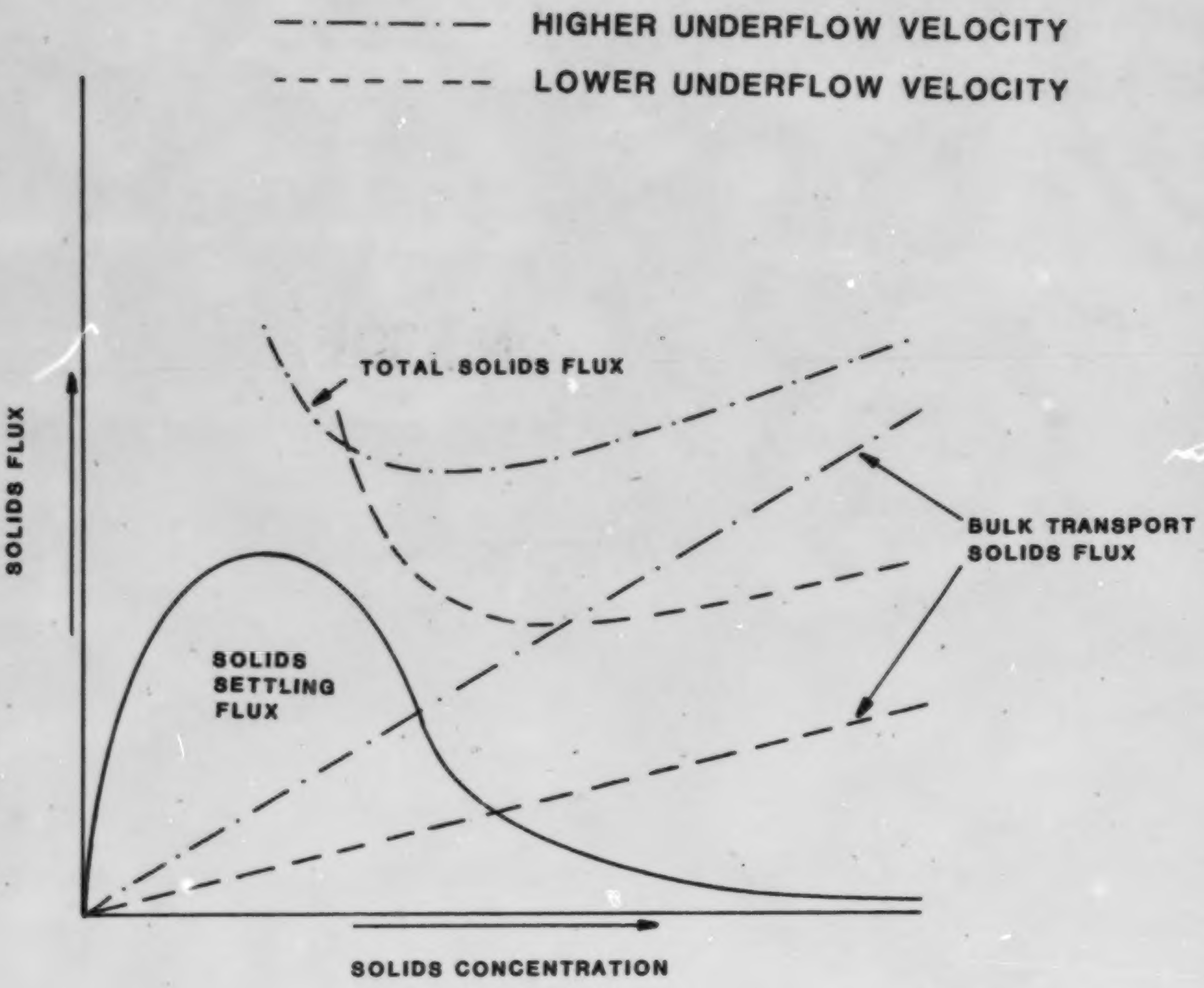
INTERPRETATION OF FINAL CLARIFIER SOLIDS FLUX ANALYSIS

179.2/11.12.20



EFFECTS OF SOLIDS SETTLING VELOCITY ON FINAL CLARIFIER SOLIDS HANDLING CAPACITY

179.2/11.12.21



EFFECT OF FINAL CLARIFIER UNDERFLOW VELOCITY ON SOLIDS HANDLING CAPACITY

179.2/11.12.22

SETTLING PROBLEMS CAUSED BY POOR SLUDGE QUALITY

- NON-BULKING

- BULKING

179.2/11.12.23

LOW SLUDGE DENSITY

*RISING SLUDGE

*ANAEROBIC SLUDGE

*OVER AERATED SLUDGE

179.2/11.12.24

RISING SLUDGE

NITRIFICATION IN THE AERATION BASIN

$$NH_4^+ \longrightarrow NO_2^- \longrightarrow NO_3^-$$

DENITRIFICATION IN THE FINAL CLARIFIER

$$NO_3^- \longrightarrow NO_2^- \longrightarrow N_2$$

ANOXIC CONDITIONS IN THE SLUDGE BLANKET

179.2/11.12.26

ANAEROBIC SLUDGE

CAUSE:

ANAEROBIC DECOMPOSITION IN FINAL CLARIFIER

CURES:

1. DECREASE CLARIFIER SLUDGE DETENTION TIME
2. INCREASE AERATION BASIN D.O.
3. IMPROVE CLARIFIER O&M
4. CORRECT CLARIFIER DESIGN DEFECIENCIES

OVER AERATED SLUDGE

- SLUDGE IS OVER STABILIZED
- TRAPPED AIR BUBBLES
- EXCESS GREASE PROMOTES AIR CAPTURE
- MECHANICAL RUPTURE OF FLOC
- ASH AND CELL DEBRIS

SETTLING PROBLEMS CAUSED BY POOR FLOC FORMATION

- ° DISPERSED GROWTH
- ° DEFLOCCULATION
- ° PIN–FLOC
- ° STRAGGLER FLOC

DISPERSED GROWTH

- NO FLOCCULATION OR SETTLING
- CONTAINS SHORT FILAMENTS, YEAST CELLS AND FLAGELLATED PROTOZOANS, DISPERSED BACTERIA
- CHARACTERISTIC OF OVERLOADED SYSTEMS
  F/M > 2.0
- FREQUENTLY ENCOUNTERED DURING PLANT START-UP
- NOT CONSIDERED TO BE A TRUE "ACTIVATED SLUDGE"

DEFLOCCULATION

- FLOC BREAKS UP EASILY
- CAUSES
  - SHOCK LOADS
  - CHANGE IN WASTE
  - TOXIC SUBSTANCES
  - EXTREME pH
  - MECHANICAL SHEAR

PIN-FLOC

SMALL FLOC PARTICLES REMAIN IN SUSPENSION

STABLE, LOW BOD PARTICLES

NORMALLY ASSOCIATED WITH:

- LOW F/M
- OLD SLUDGE
- LONG SLUDGE AERATION TIME
- NITRIFICATION
- OVER-AERATION

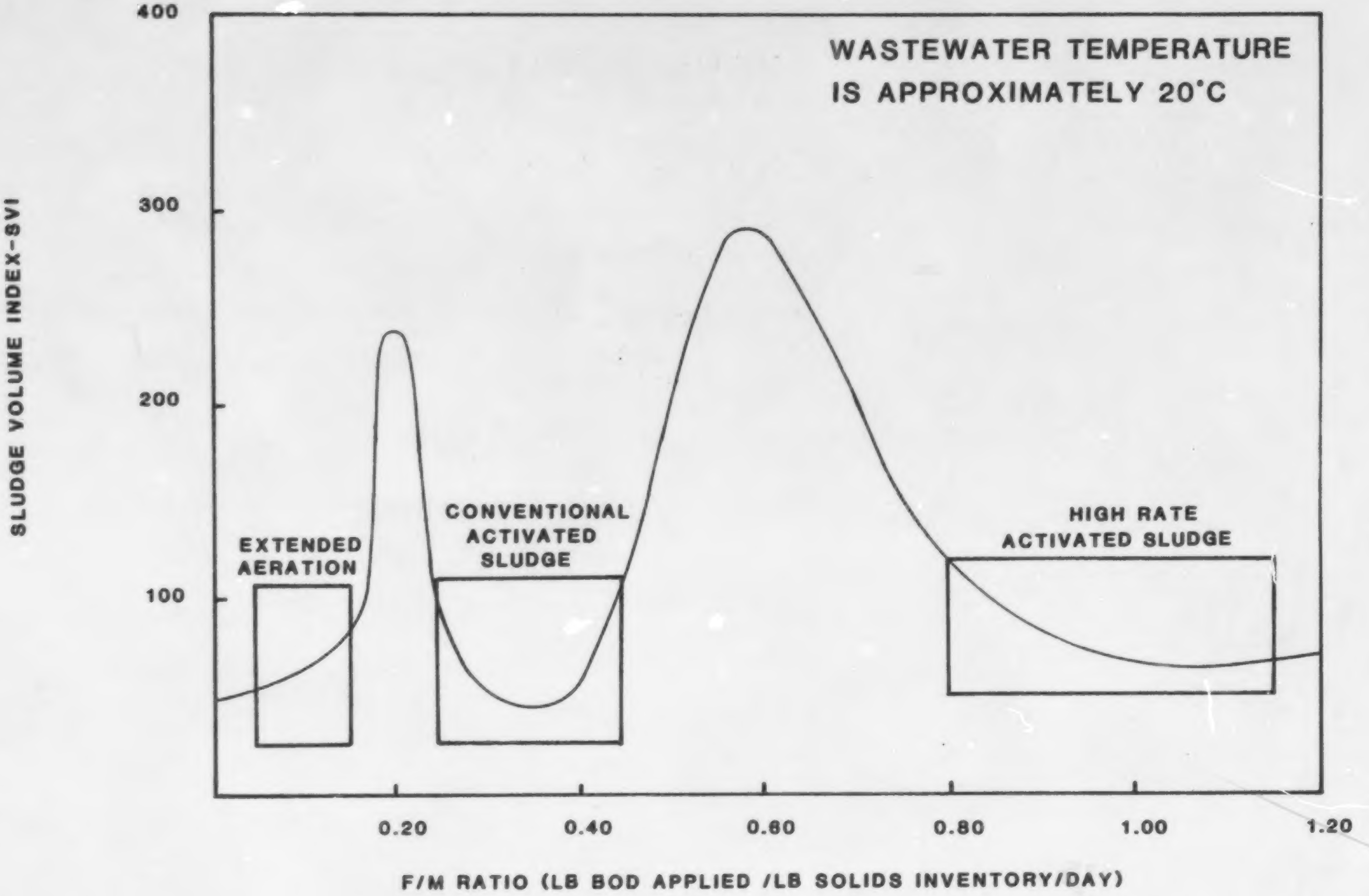
STRAGGLER FLOC

- ° SLOW SETTLING FLOC PARTICLES
- ° RELATIVELY UNSTABLE, HIGH BOD PARTICLES
- ° NORMALLY ASSOCIATED WITH:
  - · SLIGHT ORGANIC OVERLOAD
  - · F/M HIGHER THAN OPTIMUM
  - · YOUNGER SLUDGE
  - · LOW SOLIDS INVENTORY
  - · SHORT MCRT

BULKING SLUDGES

* FILAMENTOUS

* NON-FILAMENTOUS



SLUDGE SETTLEABILITY VS. ORGANIC LOADING

179.2/11.12.44

1694

WASTE CHARACTERISTICS ASSOCIATED WITH FILAMENTOUS BULKING

- ORGANIC OVERLOAD
  - HIGH SOLUBLE ORGANIC CONCENTRATION
  - SHOCK LOADS
  - TEMPERATURE
- NUTRIENT IMBALANCE
  - BOD: N > 20:1
  - BOD: P > 100:1
  - P < 2 MG/L
  - C: N > 10:1
- TOXIC SUBSTANCES
- SEPTIC SEWAGE
- HYDRAULIC OVERLOAD

179.2/11.12

AERATION BASIN CONDITIONS ASSOCIATED WITH FILAMENTOUS BULKING

- pH
  - PREFERRED RANGE: $6 < pH < 9$
  - DEFLOCCULATION AT $pH < 5$
- TEMPERATURE
- DISSOLVED OXYGEN
  - PREFERRED RANGE: 1 MG/L < D.O. < 3 MG/L
  - CONDITIONS FAVOR FILAMENT GROWTH WHEN:

D.O. < 1 MG/L

D.O. > 6 MG/L

AVOIDING BULKING

MONITOR AND RESPOND TO CHANGE IN:

- F/M
- SOLIDS INVENTORY
- MCRT
- MLSS SETTLEABILITY
- MICROSCOPIC OBSERVATIONS
- RESPIRATION RATE
    - MLSS
    - FED SLUDGE
- INFLUENT FLOW RATE

OPERATING WITH BULKY SLUDGES

- MAY PRODUCE EXCELLENT EFFLUENT
- PROBLEM: KEEPING SLUDGE IN THE CLARIFIER
- DANGER: SOLIDS WASHOUT

179.2/11.12.48

OPERATING WITH BULKY SLUDGE

- REDUCE RETURN SLUDGE FLOW RATE
- DECREASE WASTING
- MAINTAIN SLUDGE BLANKET IN LOWER HALF OF CLARIFIER

SHOULD WASTING BE INCREASED TO CONTROL BULKING

- USUALLY NO !!!
- SPECIAL CASE
  - RUN SETTLING TEST USING MLSS DILUTED WITH FINAL EFFLUENT

% MLSS	% FINAL EFFLUENT
100	0
75	25
50	50

  - CALCULATE AND PLOT SSC VALUES FOR EACH DILUTION
  - IF DILUTED SAMPLES CONCENTRATE AS WELL OR BETTER THAN THE UNDILUTED SAMPLE THEN WASTING MAY BE ADVISED

SETTLING AIDS

* ACTIVATED CARBON
* CLAY
* HYDRATED LIME
* DIGESTED SEWAGE SOLIDS
* ALUM
* FERRIC SALTS
* POLYMERS

PROCESS CONTROL TO CURE BULKING

- REDUCE RETURN RATE
- STOP WASTING
- INCREASE SOLIDS INVENTORY
- USE SLUDGE REAERATION
- INCREASE AERATION BASIN D.O.

AIDS TO CURE BULKING

- ADD DISINFECTANT
  - CHLORINATE RETURN
    - 2-3 #CL_2/1000 #MLSS
    - 10-20 MG/L CL_2
    - 5-7 CL_2/1000 #MLSS MAY CAUSE DEFLOCCULATION
  - CHLORINATE STALE OR SEPTIC SEWAGE
  - HYDROGEN PEROXIDE
- FEED ALUM
  - 8-12 MG/L FOR 24 HOURS
  - ADD LIME TO MAINTAIN pH IN RANGE 6.2-6.6

SETTLEABLE SOLIDS
SLUDGE QUALITY

GOOD	BAD
⊕ SETTLES FAIRLY RAPIDLY	⊕ SETTLES VERY FAST OR VERY SLOWLY
⊕ CONCENTRATES UNIFORMLY IN 30 TO 60 MINUTES	⊕ CONCENTRATES VERY RAPIDLY (30 MINUTES) OR VERY SLOWLY (2-4 HOURS)
⊕ FLOCCULENT	⊕ GRANULAR OR EXCESSIVELY FLUFFY
⊕ CLEAR SUPERNATE	⊕ CLOUDY, TURBID, STRAGGLER FLOC, PIN FLOC OR ASHING
⊕ DEEP TAN TO BROWN	⊕ LIGHT TAN, VERY DARK BROWN OR BLACK

FACTORS AFFECTING SLUDGE QUALITY

WASTE CHARACTERISTICS

- QUANTITY OF ORGANICS APPLIED
- CONCENTRATION OF APPLIED ORGANICS
- TYPE OF APPLIED ORGANICS
- HYDRAULIC LOAD
- NUTRIENTS
- TOXIC OR INHIBITORY SUBSTANCES

SLUDGE SETTEABILITY

- TYPE OF ORGANISMS
- SOLIDS INVENTORY
- AERATION BASIN DETENTION TIME
- SLUDGE AREATION TIME
- TEMPERATURE

AERATION RATE

CONTROLLABLE VARIABLES IN ACTIVATED SLUDGE SYSTEMS

- RETURN SLUDGE FLOW RATE
- WASTE SLUDGE FLOW RATE
- AERATION RATE
- AERATION VOLUME
- AERATION CONTACTING PATTERN

ACTIVATED SLUDGE PROCESS CONTROL PARAMETERS

- F/M
- MCRT
- SETTLEABILITY
- RESPIRATION RATE
- MICROSCOPIC OBSERVATIONS
- SLUDGE BLANKET DEPTH

179.2/11.14.5

FINAL CLARIFIER SOLIDS SETTLING PROBLEMS

FINAL CLARIFIER PHYSICAL DEFECTS

- DESIGN
- O&M

SLUDGE QUALITY

- LOW SLUDGE DENSITY
- POOR FLOC FORMATION
- POOR COMPACTION

1792/11.14.6

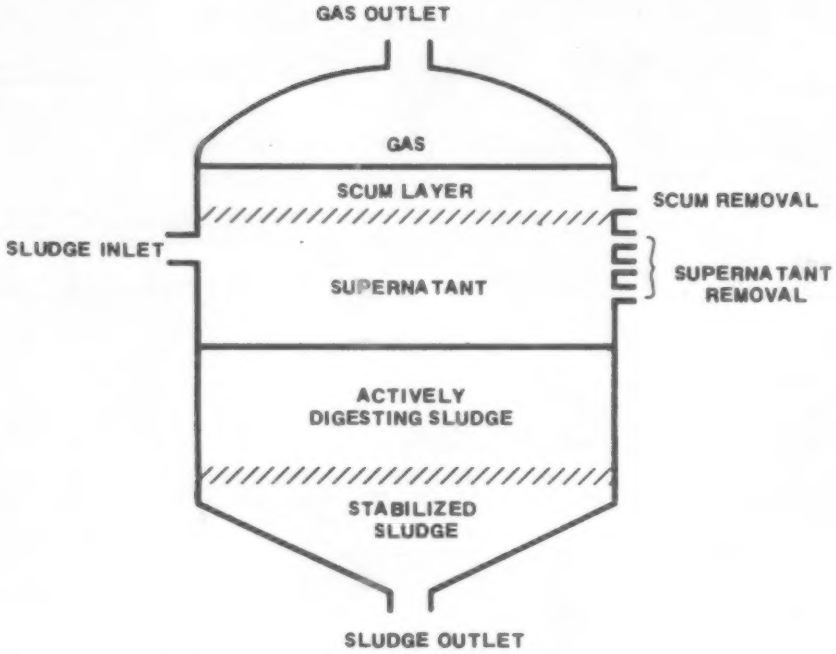
SOLIDS HANDLING SYSTEMS

179.2/12.1.2

PURPOSE OF LESSON

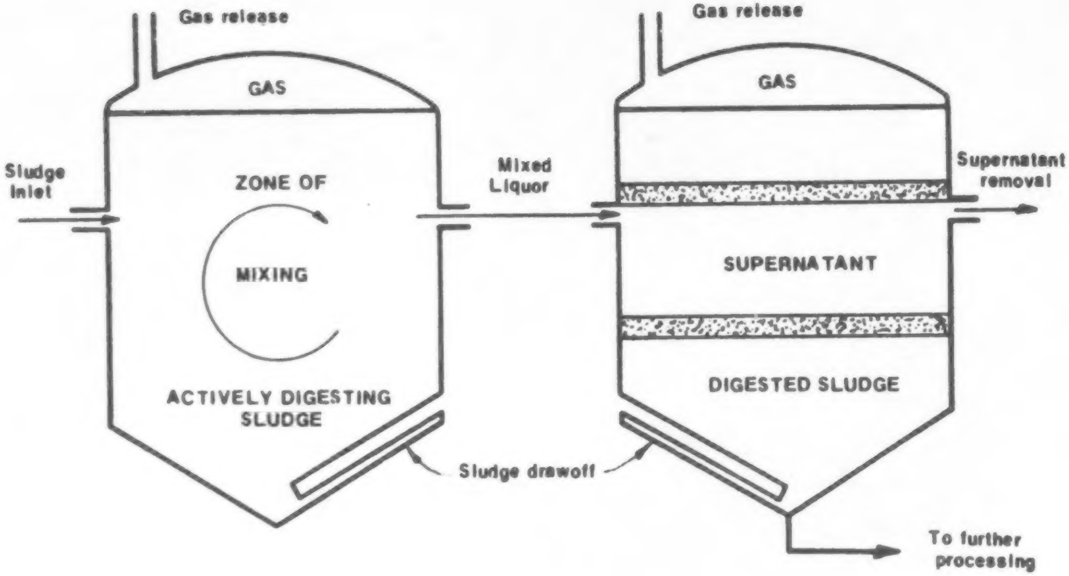
1. TO IDENTIFY AND INVESTIGATE PROBLEMS
2. TO REVIEW THE CAUSES OF SUCH PROBLEMS, HOW THEY ARE IDENTIFIED AND HOW THEY ARE SOLVED
3. TO STRESS THE USE OF THE PROCESS OF TROUBLESHOOTING
4. TO FOCUS ON TROUBLESHOOTING BEHAVIOR AND THE WAYS IN WHICH THE TROUBLESHOOTERS CAN PROVIDE TECHNICAL ASSISTANCE

179.2



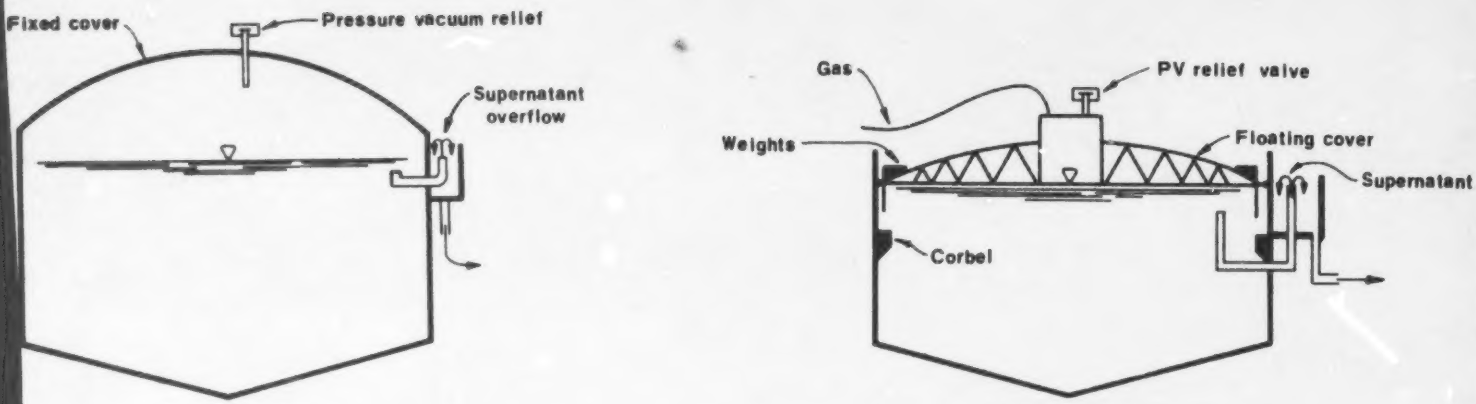
LOW RATE DIGESTER

179.2/12.1.6



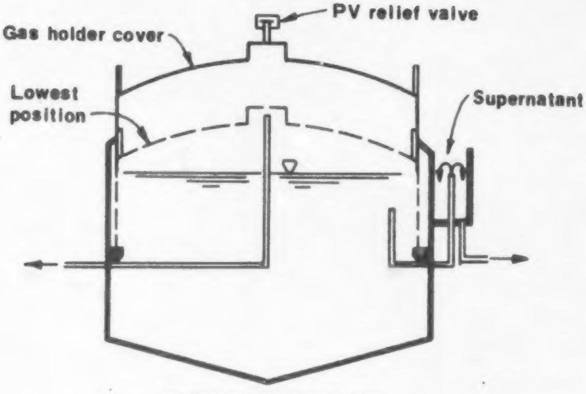
TWO-STAGE DIGESTER

179.2/12.1.7



FIXED COVER

FLOATING COVER



GAS HOLDER COVER

FIXED AND FLOATING DIGESTION COVERS

179.2/12.1.10

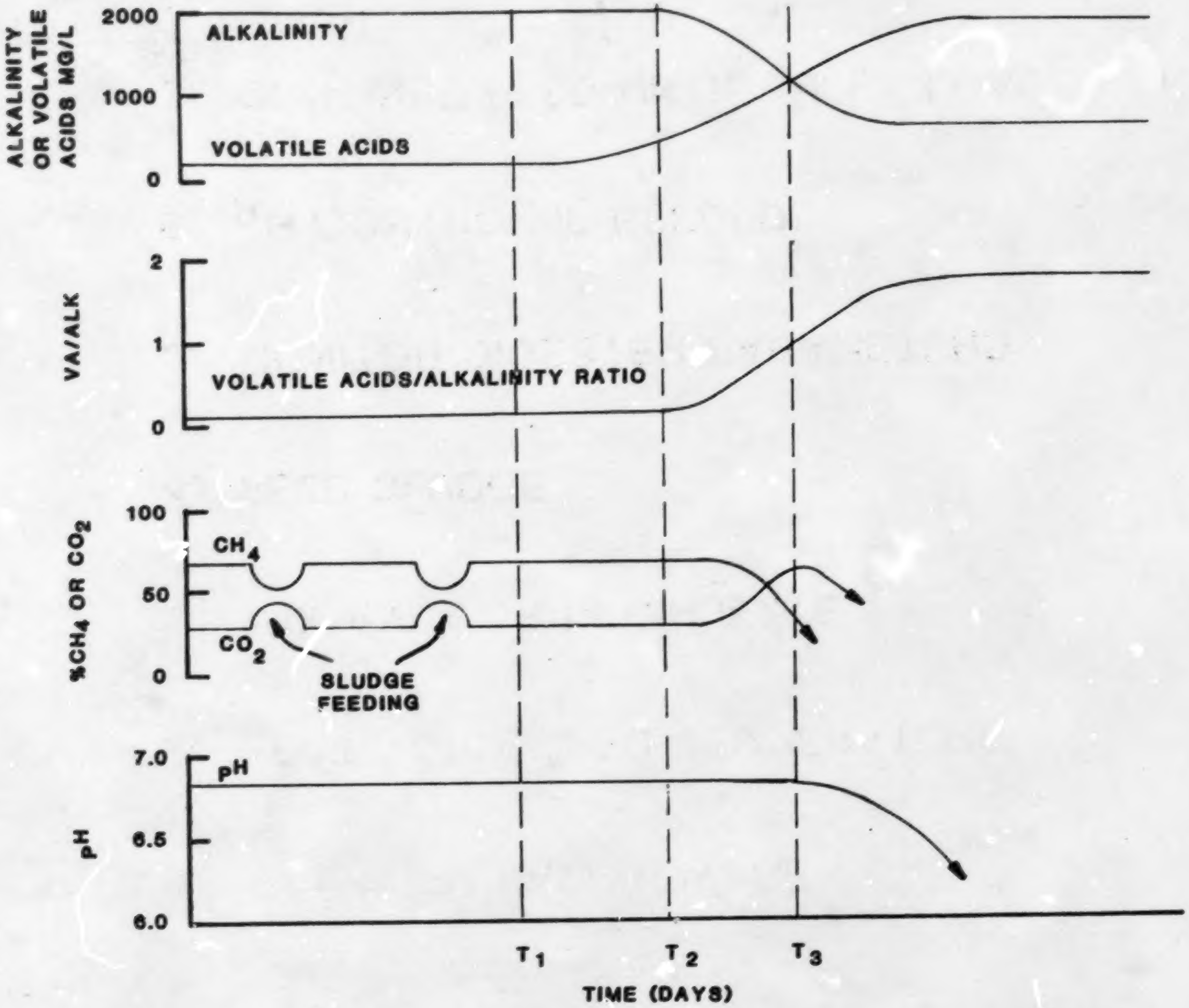
ANAEROBIC DIGESTER PARAMETERS

PARAMETER	OPTIMUM	LIMITS
pH	6.8-7.2	6.4-7.4
TEMP (°F)		
-MESOPHILIC	86-95	77-104
-THERMOPHILIC	122-131	113-140
VOLATILE ACIDS, MG/L	50-500	LESS THAN 2000
ALKALINITY, MG/L	1500-3000	1000-5000
VOL ACIDS/ ALKALINITY RATIO	0.1-0.2	LESS THAN 0.5
SOLIDS FEED ,%	3-8% PRIMARY 1-2% WAS 3-5% MIXED	

TOXIC CONDITIONS

TOXIC MATERIALS	CONC, MG/L CAUSING TOXICITY
SODIUM	5000–8000
POTASIUM	4000–10,000
CALCIUM	2000–6000
MAGNESIUM	1200–3500
AMMONIA	1500–3000
SULFIDE, SOLUBLE	200
HEAVY METALS (EX) COPPER, ZINC, LEAD, NICKEL	CONCENTRATION DEPENDS UPON THE SULFIDE CONCENTRATION CONCENTRATIOR

179.2/12.1.17



TIME SEQUENCE OF EVENTS IN A DIGESTER FAILURE

179.2/12.1.19

DIGESTER START-UP

1. FILL WITH RAW SEWAGE
2. HEAT TO DESIRED TEMPERATURE
3. MIX AND/ OR RECIRULATE
4. FEED SLUDGE
5. MONITOR DIGESTER PARAMETERS
6. pH CONTROL IF NEEDED
7. CONTINUE FEED UNTIL FULLY LOADED AND STABLE

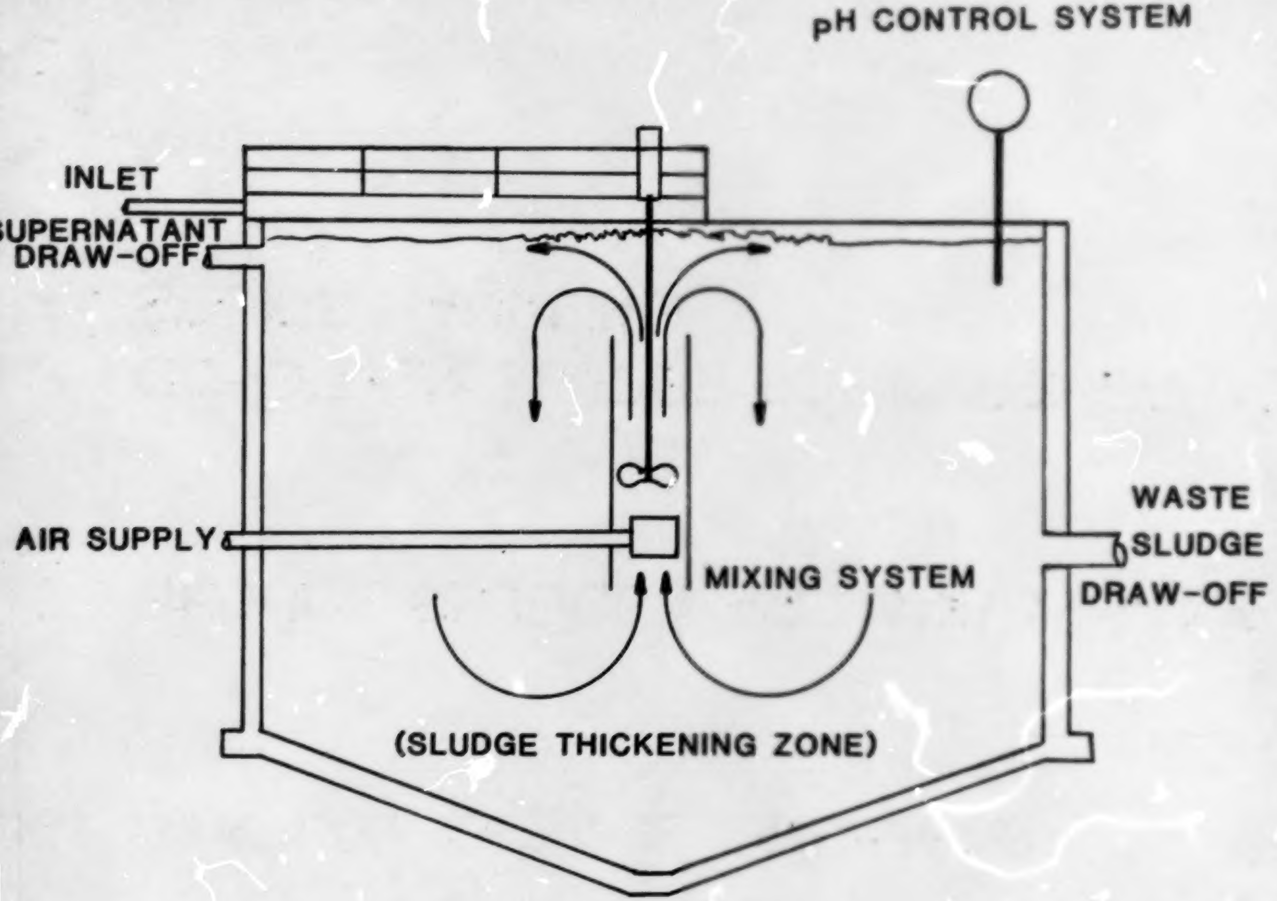
179.2/12.1.20

OBJECTIVES OF AEROBIC SLUDGE DIGESTION

1. STABLIZE SLUDGE ORGANICS

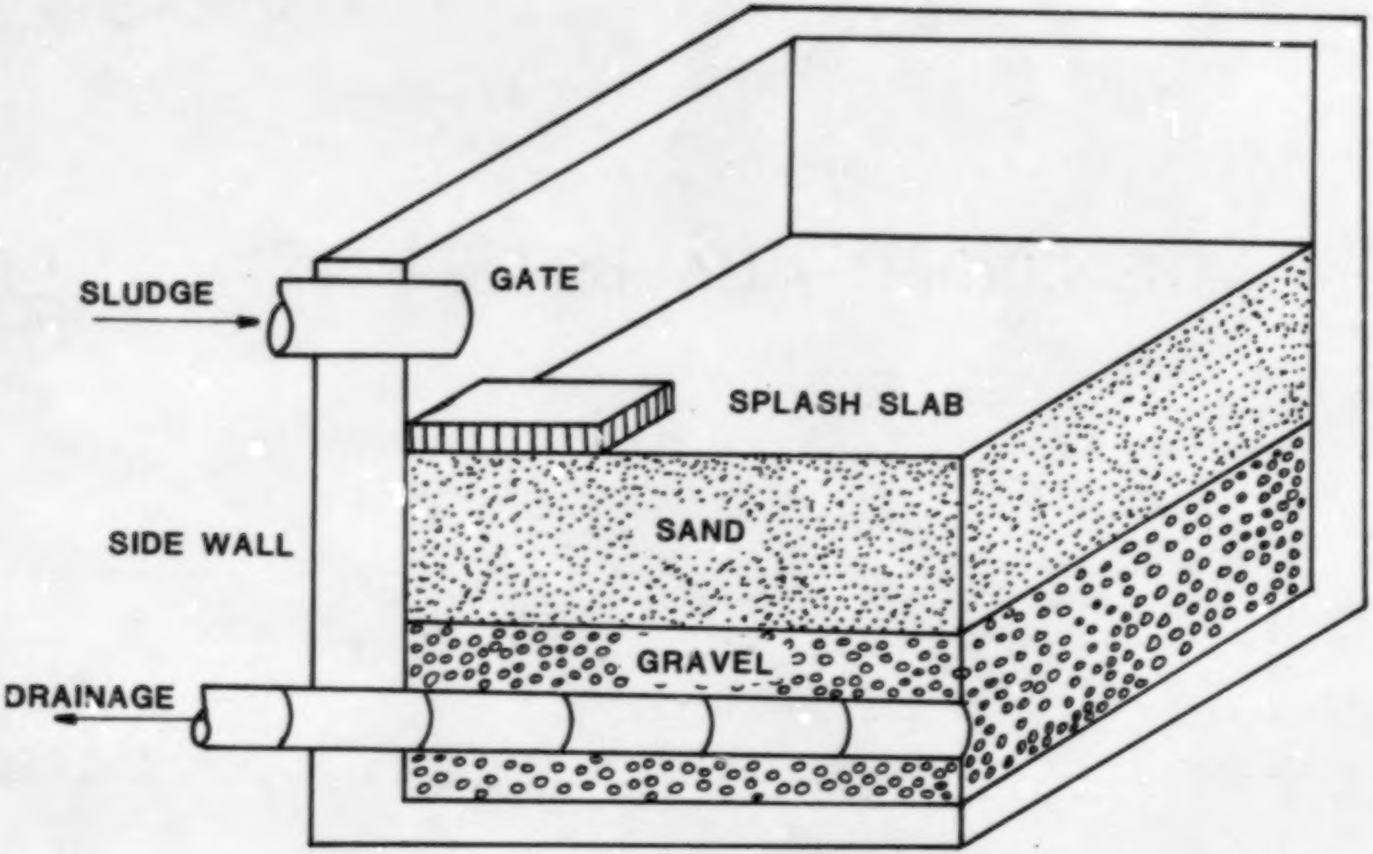
2. REDUCE SLUDGE MASS AND VOLUME

3. CONDITION SLUDGE FOR FURTHER SOLIDS HANDLING



AEROBIC DIGESTER DIAGRAM

179.2/12.3.5

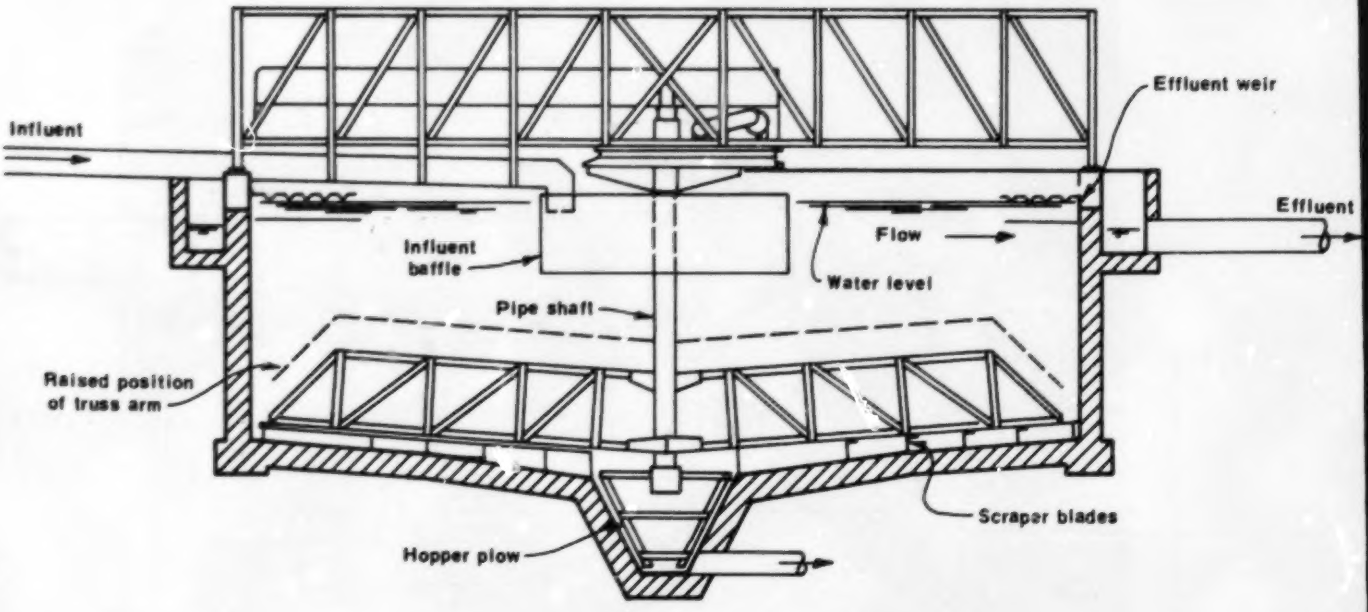


SLUDGE DRYING BED

179.2/12.3.20

1726

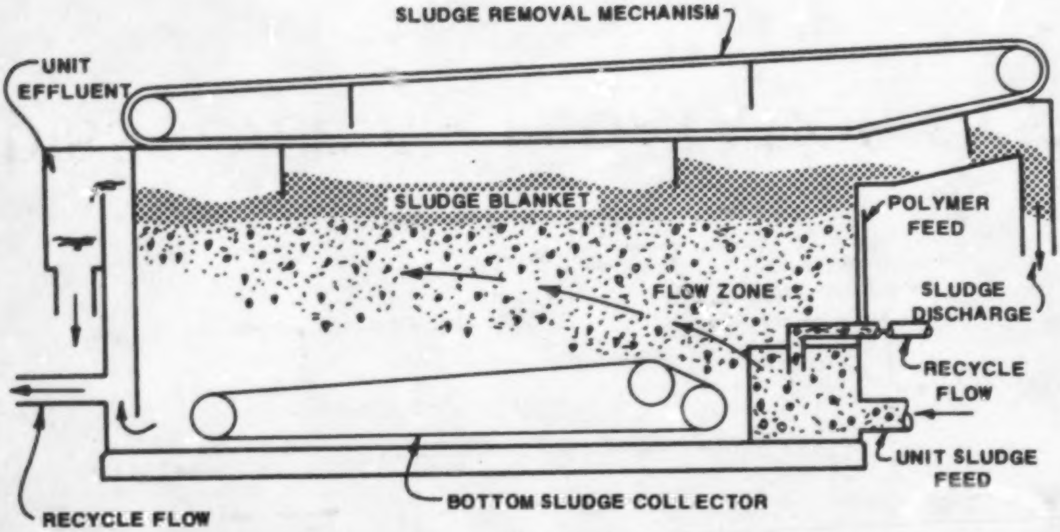
1727



GRAVITY THICKENER

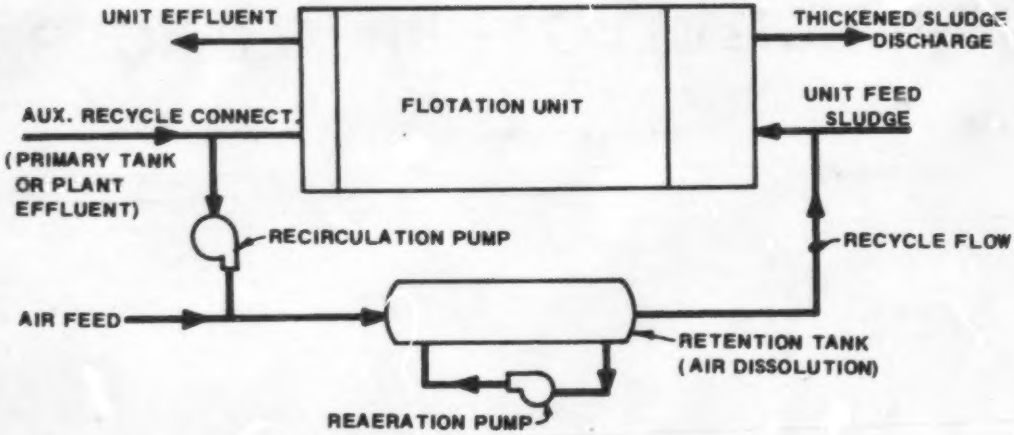
179.2/12.3.25

17?8



DISSOLVED AIR FLOATATION UNIT

179.2/12.3.30



DISSOLVED AIR FLOATATION SYSTEM

179.2/12.3.31

SLUDGE TREATMENT PROCESSES

THICKENING (BLENDING)

STABILIZATION (REDUCTION)

CONDITIONING (STABILIZATION)

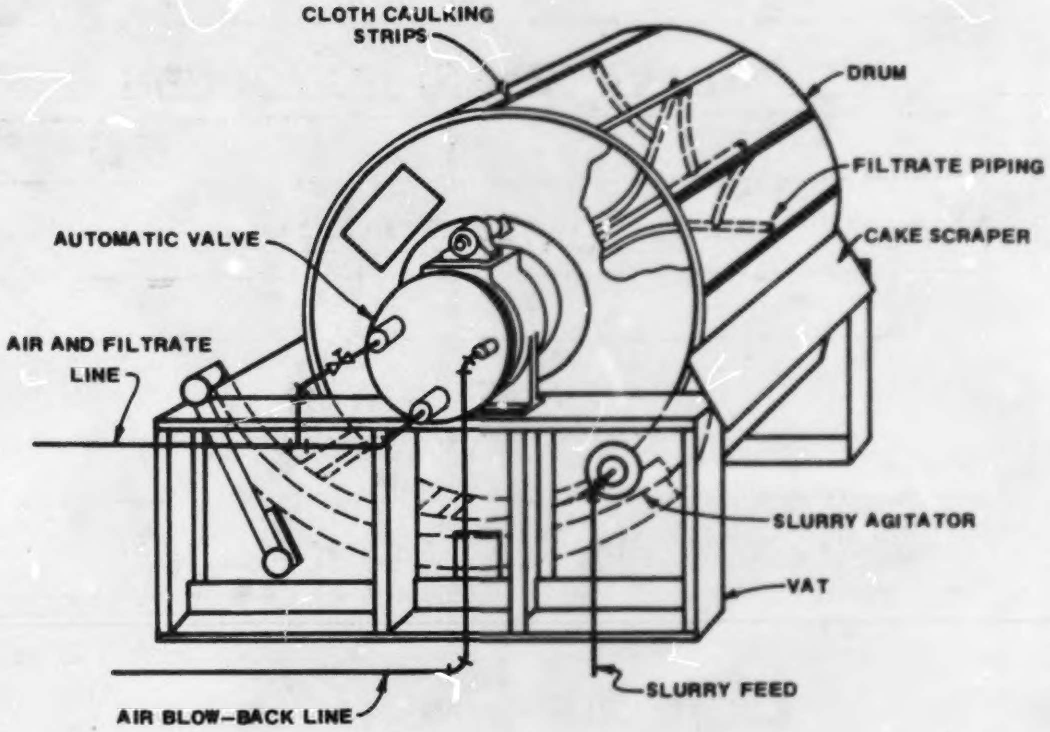
DEWATERING

HEAT DRYING

REDUCTION (STABLIZATION)

FINAL DISPOSAL

179.2/12.1.33



CUTAWAY VIEW OF A ROTARY DRUM VACUUM FILTER

179.2/12.3.37

1732

BEHAVIOR OF CHLORINE

- NON-FLAMMABLE
- NON-EXPLOSIVE
- NON-CONDUCTIVE ELECTRICALLY
- CORROSIVE IN PRESENCE OF MOISTURE
- HIGHLY REACTIVE
- OXIDIZING AGENT

179.2/14.1.4

PROPERTIES OF CHLORINE

- GREENISH YELLOW GAS
- 2.5 TIMES HEAVIER THAN AIR
- SLIGHTLY SOLUBLE IN WATER
- PUNGENT AND IRRITATING ODER
- PRESSURE CHANGES WITH TEMPERATURE

179.2/14.1.3

DISINFECTION

PURPOSE:

TO REMOVE (KILL) PATHOGENIC ORGANISMS TO A SPECIFIC SAFE LEVEL

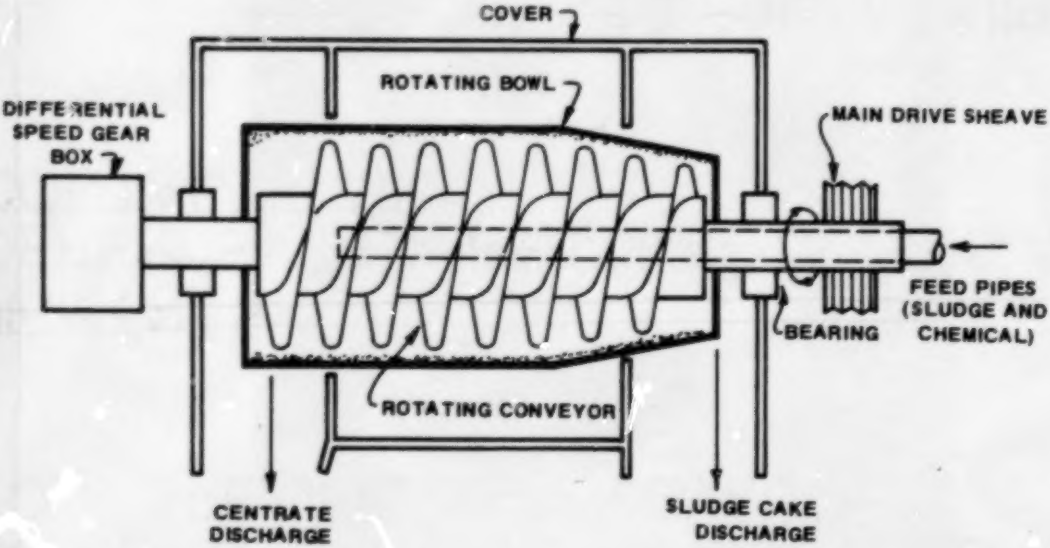
REQUIRMENTS:

DEPENDENT ON RESIDUAL LEVELS AND CONTACT TIME

CONTROL:	GENERAL REQUIRMENTS (VARIES)
*COMBINED CHLORINE RESIDUAL	*NOT TO EXCEED 0.5 MG/L
*FECAL COLIFORM	*200 F.C./100 ML GEOMETRIC MEAN

179.2/14.1.2

CENTRIFUGATION–SOLID BOWL TYPE



179.2/12.3.43

HEALTH HAZARDS OF CHLORINE

- EXCESSIVE AMOUNT IS FATAL
- NOT CUMULATIVE
- IRRATATING TO EYES AND SKIN
- RESPIRATORY SYSTEM IS VULNERABLE

179.2/14.1.5

EMERGENCY EQUIPMENT TO HAVE

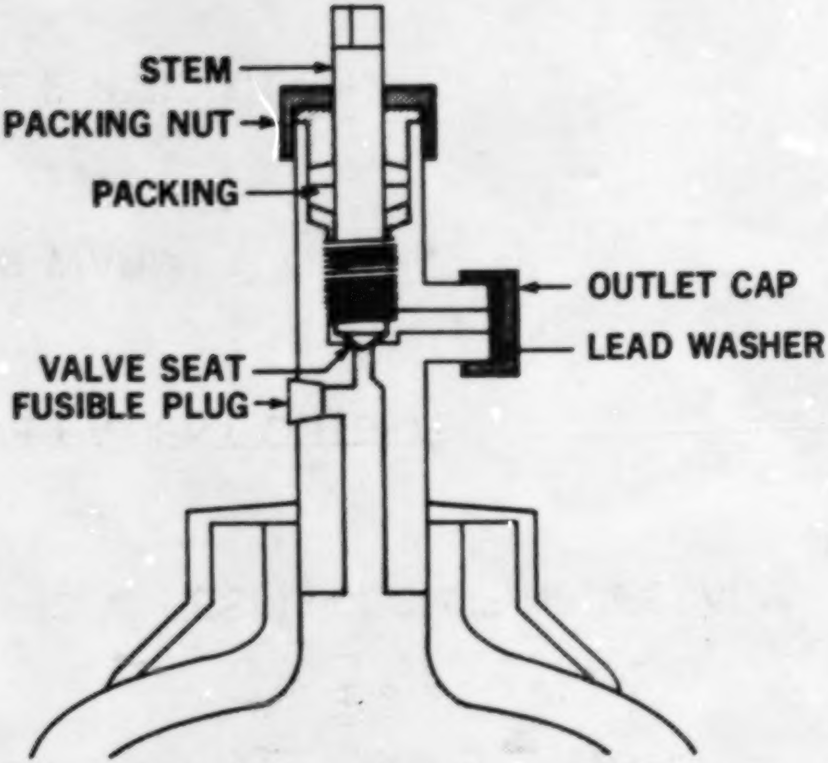
- GAS MASK OUTSIDE CHLORINE ROOM
- EMERGENCY KIT
- ALKALI OR ALKALI SOLUTION
- AMMONIA WATER
- AIR PACK
- GOGGLES AND BOOTS

170.2/14.1.6

FIRST AID FOR CHLORINE EXPOSURE

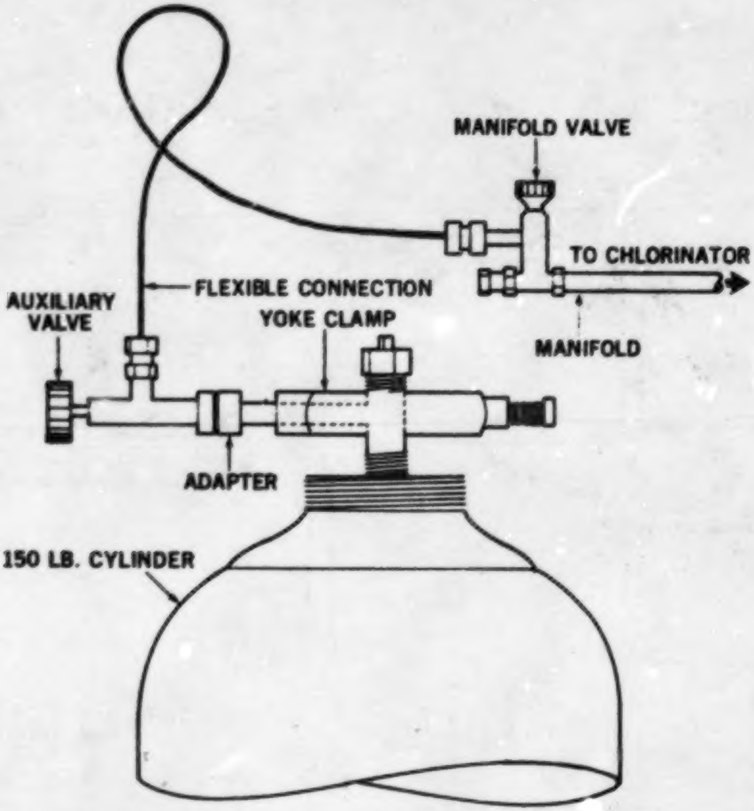
- FLUSH EYES AND SKIN WITH WATER
- ARTIFICIAL RESPIRATION IF NECESSARY
- MOVE PATIENT OUTSIDE
- KEEP WARM
- CALL PHYSICIAN

179.2/14.1.7



VALVE COMPONENTS ON 150 LB CHLORINE CYLINDER

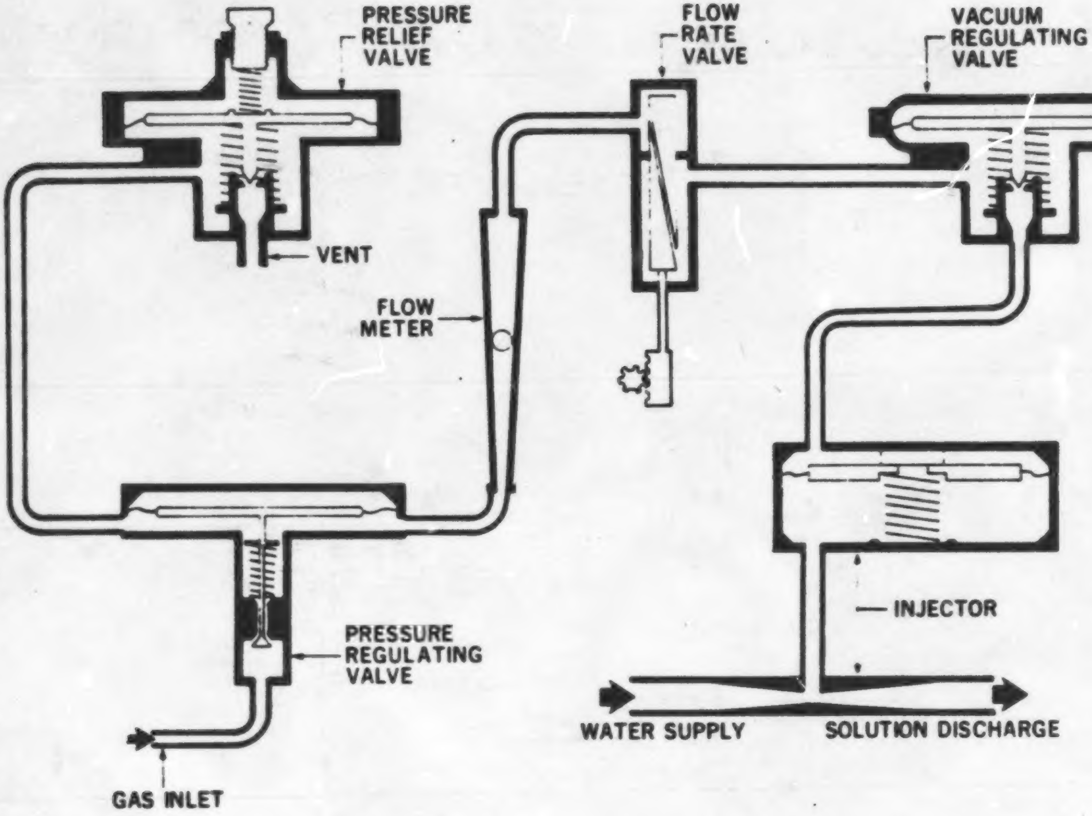
179.2/14.1.8



MANIFOLD CONNECTION FOR 150 LB CHLORINE CYLINDER

179.2/14.1.9

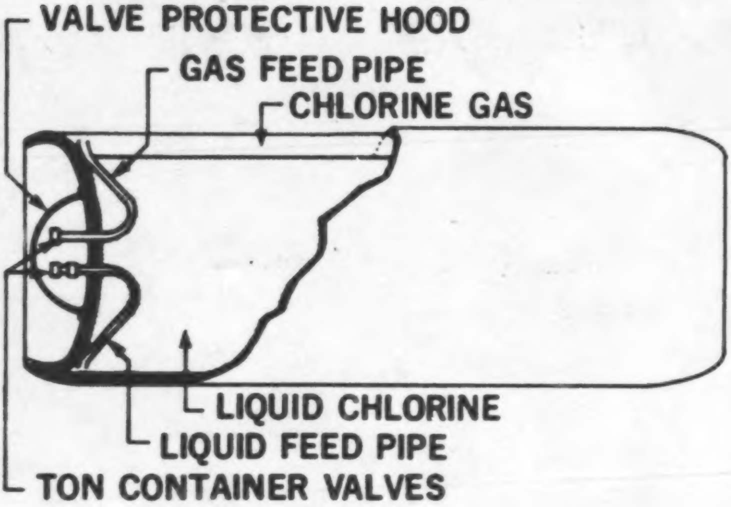
1742



SCHEMATIC DIAGRAM OF GAS CHLORINATOR

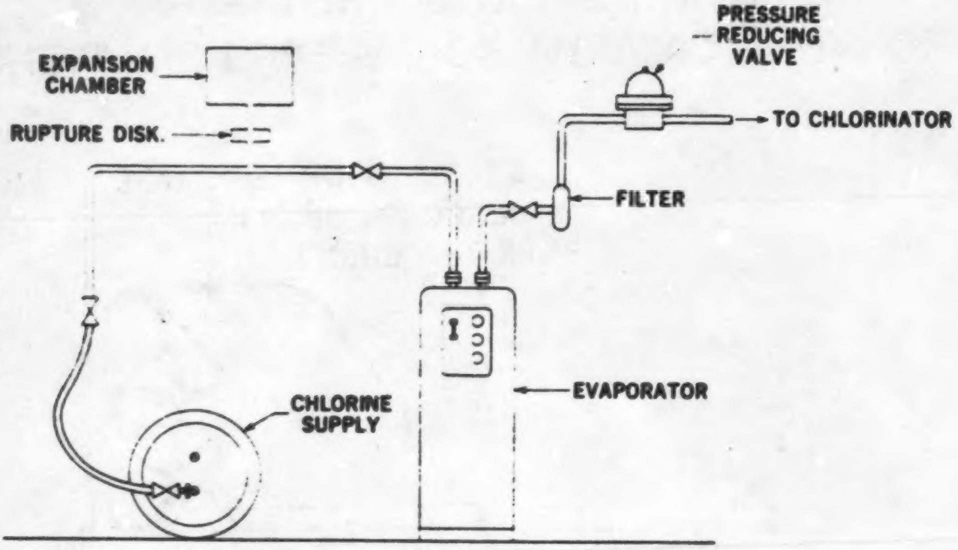
179.2/14.1.10

1743



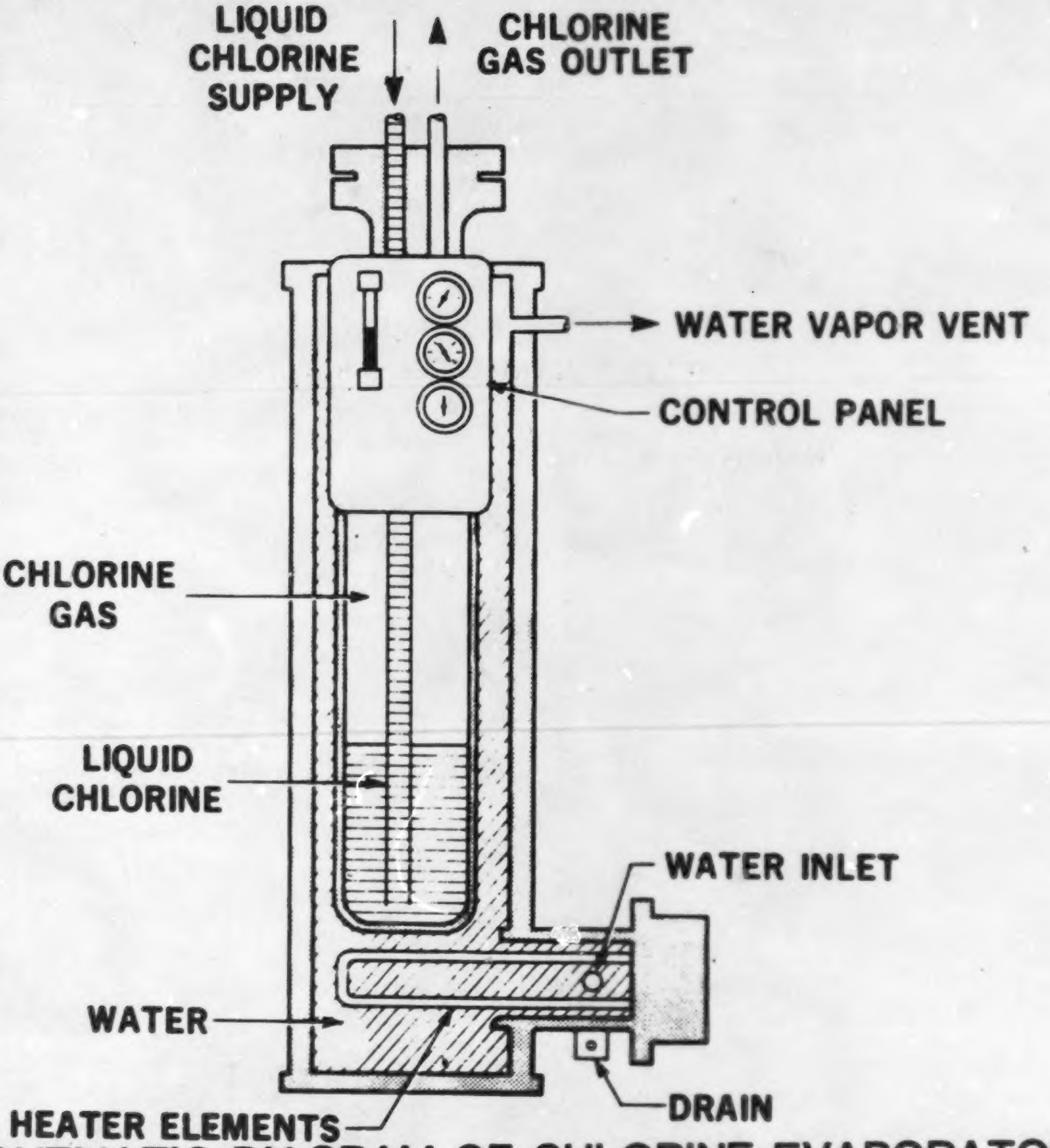
SCHEMATIC DIAGRAM OF VALVING ARRANGEMENT FOR TON CHLORINE CYLINDER

179.2/14.1.11



SCHEMATIC DIAGRAM OF CHLORINATION SYSTEM USING TON CYLINDER

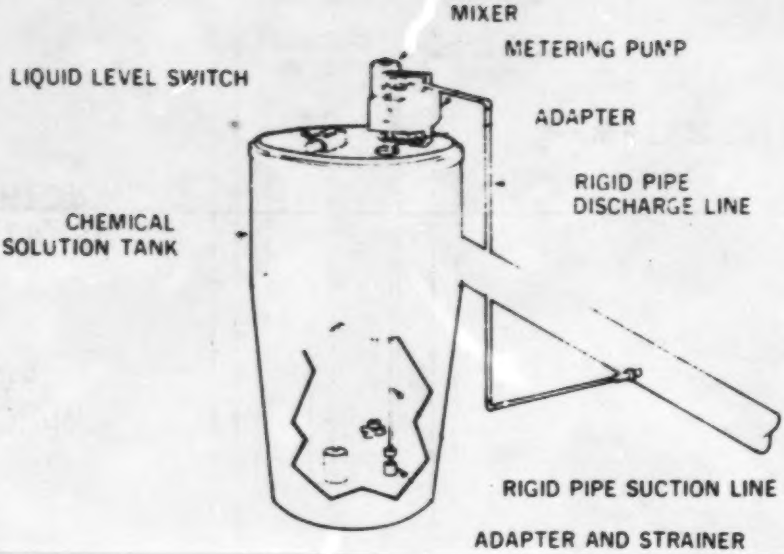
179.2/14.1.12



SCHEMATIC DIAGRAM OF CHLORINE EVAPORATOR

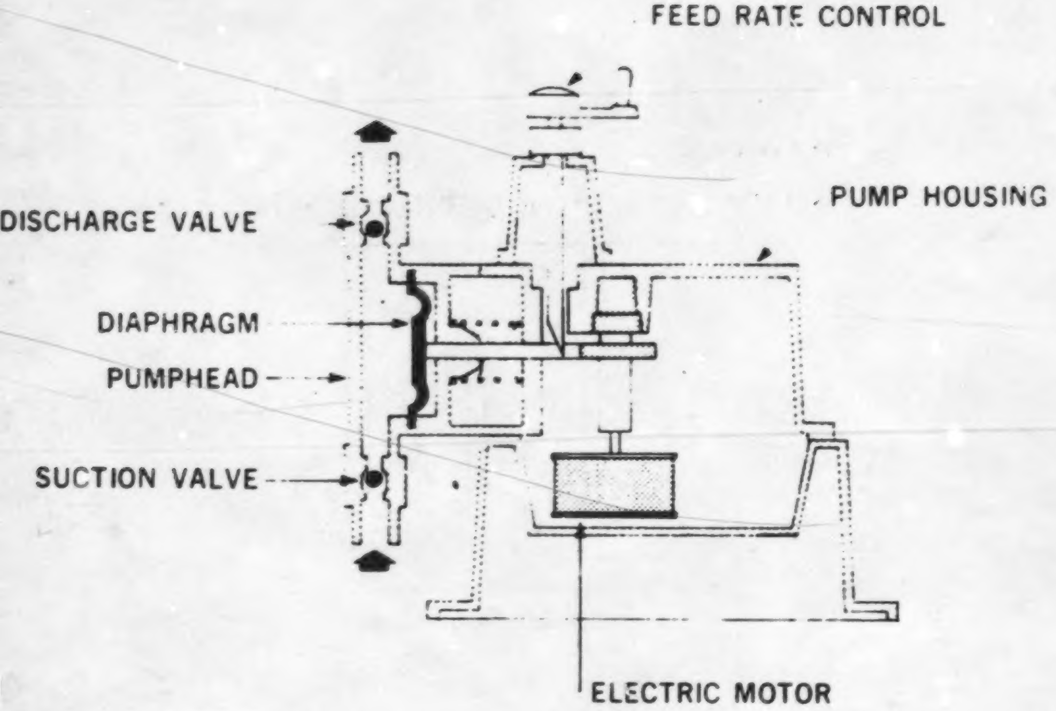
1746

179.2/14.1.13



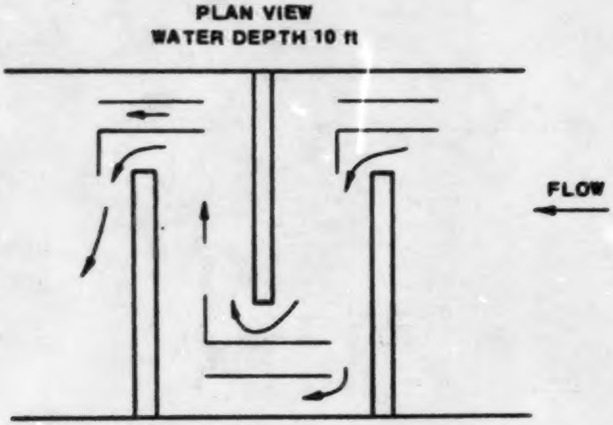
TYPICAL HYPOCHLORINATION SET-UP

179.2/14.1.14



DIAPHRAGM SOLUTION METERING PUMP

179.2/14.1.15



TYPICAL CHLORINE CONTACT CHAMBER

179.2/14.1.16

UPGRADING CHLORINE CONTACT TANKS – IMPROVE DISINFECTION

- IMPROVE MIXING CHARACTERISTICS

- ELIMINATE SHORT CIRCUITING

- IMPROVE CHLORINE DIFFUSER SYSTEM

- LENGTHEN CONTACT TIME

179.2/14.1.17

OZONE – O_3

IN HIGH VOLTAGE ELECTRICAL DISCHARGE

$$O_2 \rightleftharpoons O + O$$

$$O + 2\,O_2 \rightleftharpoons O_3 + O_2$$

IN AQUEOUS SOLUTION

$$O_3 \rightleftharpoons O_2 + O$$

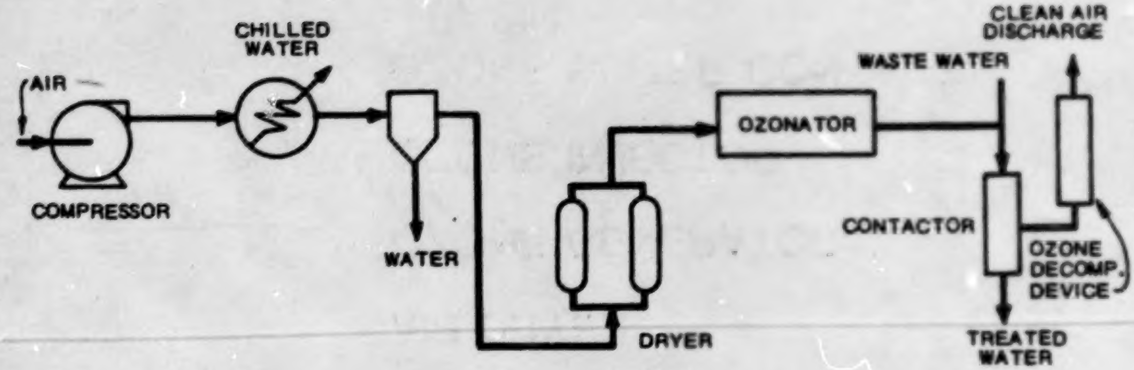
$$O + O_3 \rightleftharpoons 2\,O_2$$

179.2/14.2.2

OZONE SYSTEM COMPONENTS

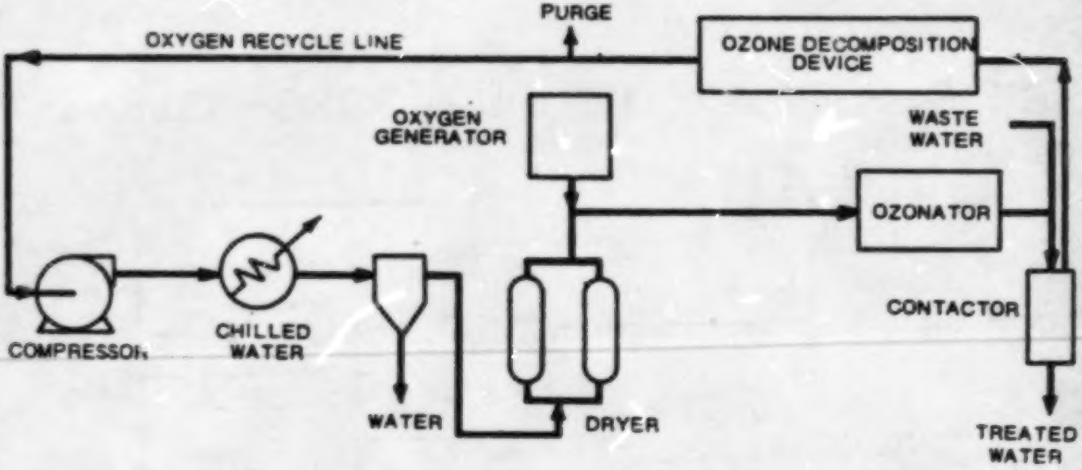
- AIR BLOWER
- AIR FILTER
- AIR COOLER
- AIR DRYER
- OZONE GENERATOR
- OZONE INJECTOR
- OZONE WATER CONTACT BASIN
- OZONE DESTRUCTION SYSTEM

179.2/14.2.3



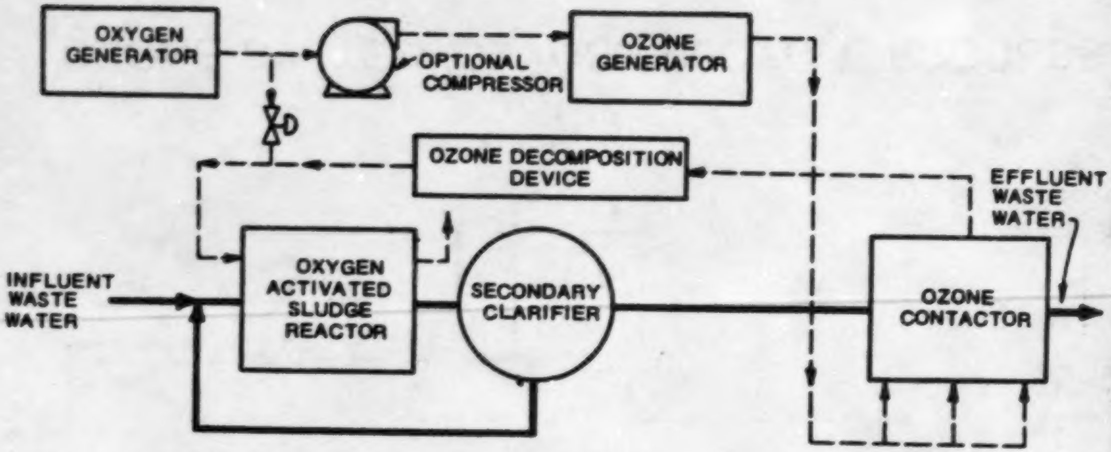
OZONE SYSTEM–ONCE THROUGH AIR PROCESS

179.2/14.2.4



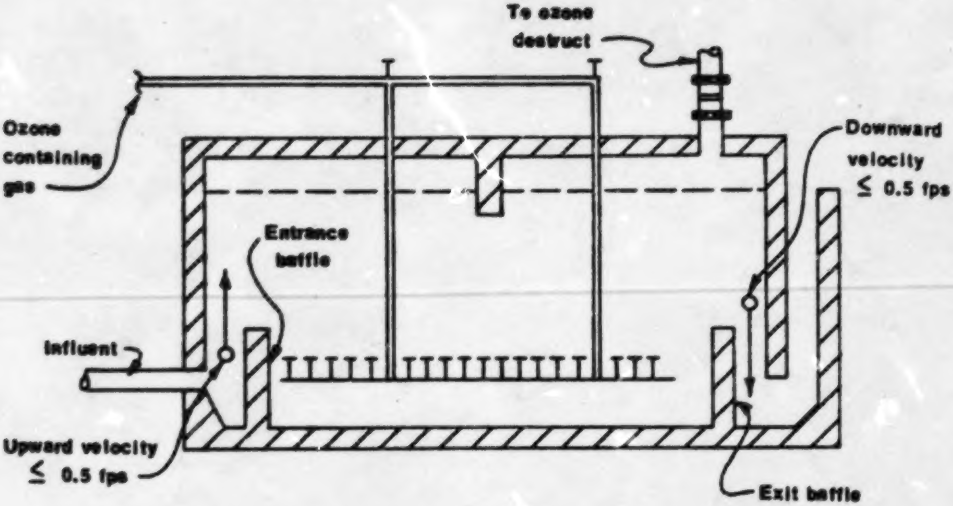
OZONE SYSTEM–OXYGEN RECYCLE PROCESS

179.2/14.2.5



OZONE SYSTEM–ONCE THROUGH OXYGEN PROCESS

179.2/14.2.6



OZONE CONTACT BASIN WITH POROUS DIFFUSERS

179.2/14.2.7